THE TELEGRAPHIC JOURNAL AND

# ELECTRICAL REVIEW.

VOL. XXVII. SEPTEMBER 26, 1890. No. 670.

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## RAILWAY ACCIDENTS FOR THE YEAR 1889.

THE Board of Trade Report on the above subject for the past year shows the total number killed in the working of railways to have been 1,076, and the number injured, 4,836. Of these 183 persons killed and 1,829 persons injured were passengers, but only 88 were killed and 1,076 injured in consequence of accidents to, or collisions between, trains. The deaths of the remaining 95 passengers, and the injuries to 813, were due to a variety of other causes, and especially to want of caution on the part of the individuals themselves.

The casualties for the year have been greatly heightened by the Armagh accident, which, it will be remembered, resulted in the death of 80 and injury to 262 children and others. Deducting this 80 killed, we have a result of 8 passengers who lost their lives from causes beyond their own control during the period, as compared with 11 for the previous year, and 25 for 1887. Making a like reduction with respect to the injured, the result is not, however, so favourable, for it leaves us with a comparison of 744 injured for 1889, as against 594 for 1888, and 538 for 1887. One is naturally inclined to make exceptions of heavy casualties such as the Armagh collision, the Tay Bridge disaster, &c., although, in point of fact, it is not quite a logical way of handling the results dealt with and considered year by year. Casting aside the exception, and looking simply at the year's result, we find that although there has been an increase of passenger journeys over those of 1888 to the extent of 2,683,909, the proportion of killed and injured to the number carried, exclusive in either case of season ticket holders, is brought down to figures very closely approximating to those of the Tay Bridge year. The result, on the whole, is not congratulatory, and we can only express a hope that future returns may not be marred by more of those heavy disasters, which cause a thrill to pass through the nation, for some years to come.

In reviewing the report, we have chiefly to deal with those portions wherein electrical apparatus plays a part, or where, had it been in use, it might have proved of service in averting disaster.

Collisions between engines and trains following one another on the same line of rails, excepting at junctions, stations, or sidings, have, during the year, been productive of but one case, resulting in injury to 13 passengers and 1 servant. This was due to a signalman omitting to signal for permission to admit a passenger train into a section in which was standing another train at the time. A heavy fog prevailed, but that in no way authorised the signalman sending the train into the section against the electrical signals. In this case, had the outdoor signals been interlocked with the electrical signals, the probability is that the train would have been held at the stop signal, and the collision avoided.

Collisions at junctions amount to four. 88 passengers and 6 servants were injured. The most serious of these was that on the Lancashire and Yorkshire, on the 7th December ; and that on the London, Chatham and Dover, on the 14th November. All of these accidents are said to be the result of want of care or judgment on the part of drivers or signalmen, and it would appear that the only way of avoiding them is to insist upon the preservation of a given space between all moving trains, or by making it obligatory upon every driver to bring his train to a dead stop before entering a junction. With the heavy traffic which now has to be dealt with at many important junctions, and the necessity of bringing forward trains for connection as readily as possible, we quite see and appreciate the difficulties which beset the question ; but still, we feel that improvements are yet to be made, probably by extending the distance of distant signals, so as to give earlier intimation to drivers when they are required to stop.

Collisions within fixed signals at stations or sidings resulted in enquiries into 25 cases, in which seven passengers and one servant were killed, and 143 passengers and 20 servants injured. Nine of these were

mainly due to mistakes in block working, arising from forgetfulness or want of care, three to mistakes of pointsmen, 11 mainly to want of care of engine drivers, one to foggy weather, two to want of proper interlocking, two to want of brake power, and two to want of block working.

The want of block apparatus will, no doubt, now be supplied—if not under the recommendation of the inspecting officer, it will under the recent powers conferred upon the Board of Trade.

There were two collisions between engines and trains meeting from opposite directions, by which 24 passengers were injured. One was due to the engine driver running against the signal, and the other to the mistake of a signal porter.

The foregoing are the main points which affect, or are affected, by the electrical branch of the railway service. The time has now come when the employment of a block system, together with that of an interlocking system for points and signals is about to be enforced. In a short time all passenger lines will be thus equipped. It is not many years since pioneers were fighting for the introduction of either. Slowly the antipathies of the old school have been worn away; in many instances by arguments of so forcible a character as to no longer admit of obstruction. To the larger, more important, and more experienced companies of England and Scotland, the demands of the Board of Trade under their recent powers means, perhaps, little more than a confirmation of what they have done—as showing they were wise in, of their own will, doing that which, had they left it undone, must now have been performed under the orders of an Act of Parliament. Yet we cannot help thinking—indeed, it is not a question of doubt with us at all—that what is now being done is, although a very important part, still only a part of what has to be done to render railway working more secure. It has been our province more than once to point out that railway train working is dependent upon a double action—first, that of the electric signals, and then that of the line signals. The driver is governed by the latter. The signalman who works them is governed by the electrical signals. With but few exceptions, the one is completely disassociated from the other. The devices adopted are made as evident as possible, but still they have to be interpreted. The signalman has to obtain the electric signal, and to convey it by his mechanical signals to the engine driver.

It is quite possible to lock the one with the other. It has been done, and is in daily use. It would probably have been too great a revolution to have asked for its application to all block signals; but as there can be no question of its great advantage, it is to be somewhat regretted that an extended use of it has not been advocated, especially upon busy parts of the various systems. Doubtless the time will come for its adoption. Although originally greatly opposed, the block has now become as much a part and portion of our railway system as the rails upon which the traffic is carried. We feel that it cannot be a great while before the propriety of coupling together those two important adjuncts which now form the controlling agent for the regulation of the traffic makes itself as apparent and as necessary to the management of the different important companies as did the earlier adoption of the block. Where this is done, we shall look for a considerable reduction in railway casualties.

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**Heating of Dynamos.**

M. RECHNIEWSKI, in a paper read before the International Society of Electricians, deals with the heating of dynamos, and thinks that the "maximum temperature which can safely be admitted for the armature is about 70°, say about 40° to 50° above the temperature of the surrounding air. At this point insulating material stands well, and the effect of increased resistance of the copper is little noticeable." We are dealing with the same subject on another page, and it will be observed that, as regards the maximum temperature permissible, M. Rechniewski's views and our own practically coincide.

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**Output of Dyamos.**

IN proceeding to consider the output M. Rechniewski points out that the rise of temperature due to hysteresis is similar in machines in which the armatures have the same peripheral velocity, provided all the linear dimensions are proportionally increased or diminished. He concludes that a machine having its linear dimensions increased $n$ times, will give an output $n^{\frac{1}{2}}$ times that of the smaller one if it is to attain in continuous running the same temperature. The means of eliminating Foucault currents, fully described in "A Synthetic Study of Dynamo Machines" some time since, also come in for a share of the author's attention.

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**Electric Tramways and Telephones.**

THE general feeling with reference to the fight between the electric tramway and the telephone companies, as to which party is to arrange matters so that the telephone circuits are to remain undisturbed by possible leakage from the electric tramways is, that the telephone companies must give way. These companies practically claim, as first comers, the sole use of the earth, and argue that the disturbance to which their circuits are liable from strong currents should be obviated by the tramway companies insulating their lines in such a way that there should be no leakage. In a recent decision by Chancellor Gibson, with reference to a dispute in Knoxville, America, the Chancellor argued that, "If the contention that no company using a strong current, can lawfully use the earth for a return current without the telephone company's leave, be correct, then no electric company can ever use the underground on which Knoxville is built without the consent of the telephone company. It makes no difference what grand discoveries and inventions in the use of electricity may be made. Coal, wood, gas, steam and animal power may all be superseded by electrical devices, machines may be invented to heat and light all of our homes, do all of our cooking, propel all of our vehicles and machinery, and all or a large part of this electricity may be drawn from the earth, or it may be drawn from the air, and yet Knoxville and her

people are to be denied all of these wonderful benefits for all the ages to come, if they, either through the earth or through the air, in any way cripple or injure the feeble current of the telephone company, unless the telephone company gives or sells its consent."

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The Right of Monopoly.

PROVIDED there were no means of curing the evil effects of the tramway currents, the contention of the telephone company would appear a good one, as the value of their system to the citizens may be just as great as that of an electric tramway, and, under such circumstances, the Chancellor's remarks would be hardly to the point. Again, the question may be, whether a monopoly was really granted to the company, it being unforeseen at the time that any other industry would spring up that would interfere with the existing system of telephones; if the monopoly were granted, then no matter how hardly it may press upon new comers this monopoly can hardly be repudiated without breach of contract, and though it should not be allowed to stay all further progress, it ought to be recognised by some compensation being given. The mere fact that it would cost the tramway company more than the telephone company to cure the evil is hardly a conclusive argument for forcing the telephone company to give way, though no doubt the latter is carrying out a dog-in-the-manger policy by taking up the course it is.

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Duplication of Telephone Wires.

THE argument that all the telephone companies have to do is to duplicate their wires may appear a very plain one, and it would be so if local working only were the order of the day; but when the working has to be over trunk lines on to other systems, it either means duplicating the trunk lines and the circuits of the other systems also, or else working with induction coil repeaters at the ends of the trunk, which is not conducive to good speaking.

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The Post Office and Electrical Disturbances.

AS regards electric light circuits, considerable trouble, we believe, has been experienced by the Postal Authorities from the action of the Ferranti mains of the London Electric Supply Corporation. In the event of this disturbance not being cured by the Corporation, is it to call upon the Department to duplicate their wires?

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The Efficiency of Arc Lamps.

WE should have thought the time had gone by for electrical journals to describe any particular arc lamp as giving more light per horse-power than another. Yet we find an esteemed American contemporary seriously assuring its readers that, with respect to one design of lamp, such is said to be the case. As a matter of fact, for the same current and difference of potentials there is produced with similar carbons the same amount of light; and while makers may endeavour to delude the public in the manner referred to, technical journals ought to be careful that they do not appear to lend themselves to the deception. Regarding the makers, we never knew one yet who did not claim that his lamp, as compared with others, took least power and gave the steadiest light.

Mitis Metal for Field Magnets.

PROFESSOR SILVANUS THOMPSON'S Cantor lectures on "The Electro-magnet" teem with practical hints. Speaking of Mitis metal, which is a kind of cast wrought iron rendered fluid by the addition of a small percentage of aluminium, Dr. Thompson states that he has found this metal far superior to ordinary cast iron, and not much inferior to wrought iron. It is well known that the field magnets of dynamos and motors are made to certain forms, mainly to avoid expensive forgings on the one hand, or inferior results with cast iron on the other. In most cases a compromise is made by using good wrought iron for the straight cores, and cast iron for the pole pieces, the latter involving difficult work if forged out of wrought iron. Mitis metal it appears, if easily produced, would bring about material deviations from existing types of field magnets, especially for the cheaper class of dynamos and motors. Indeed, a reasonably small difference in permeability may be compensated for by some advantageous design which could not hitherto be adopted in the case of wrought iron, owing to structural difficulties. Further research in this direction might lead to important results from a commercial point of view.

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Electric Traction.

IT is anticipated that Electric Traction will form an important topic of discussion during the forthcoming meetings of the several American Street Railway Associations. Until three years ago these societies not only occupied themselves exclusively with matters concerning horses, stables, manure and horse cars, but when the subject of electric haulage was mooted the introducers of the novel "fad" were looked upon with suspicion and scepticism. Times have changed with astonishing rapidity. Many of the advocates of the horse have been converted to modern ideas, others have dropped avowed opposition and are now watching events. None can upset the remarkable fact that out of 8,652 miles of tramways in the United States, 1,753 miles, or nearly 20 per cent., are now worked with electric cars. We expect, therefore, to hear of many practical results from practical men who view the present situation entirely from the financial point of view: thus we may contrast the utterances of the old-fashioned tramway man with those of the modern electrical engineer, and draw useful conclusions.

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Fatal Electric Tram Accident.

A TELEGRAM from Florence under the date of September 23rd, announces that a fatal accident occurred on the electric tramway between that city and Fiesole. The cars ran off the track, five persons being killed on the spot and 20 others injured. On being informed of the occurrence, the King and Queen and the Prince of Naples at once gave up the idea of attending the races, as had been their intention, and visited the injured. Such a fatality reflects seriously upon the tramway authorities, and there must have been either inefficient driving, badly constructed permanent way, or failure of brakes, in all of which cases the blame will be attached to the electric system by the timid public. This is all the more to be regretted since electric traction has been in a fair way of gaining public favour in Italy.

## A SYNTHETIC STUDY OF DYNAMO MACHINES.

(*Continued from page* 207.)

### IX.—THE HEATING OF MACHINES (*continued*).

As stated in our last article, the temperature attained by the best class of machines, when working in the normal atmosphere for which they are designed, seldom exceeds 75° C. On land it is generally under this, and the rise of temperature allowed from the start is most frequently from 30° to 40° C., which is, of course, included in the 75° C. mentioned above, or whatever may be the maximum attained. The evil of overheating is not perceived at once, or it may be for a long time after a machine has been set to work. The deterioration of the insulating material is gradual, and consists in its eventually "perishing" or becoming "rotten" with the continuous heatings to which it is subjected. When this condition is reached, it has lost all its original tenacity and toughness, and has become extremely brittle. The paper, calico or fibre has become of a dark colour, and the cotton covering of the wire has a semi-charred appearance. Although the insulation resistance may be as high or higher, in fact, than it was originally, the armature is more liable to break down when in this state. It is, therefore, of the greatest importance to prevent overheating, if it is desired to combine long life with high efficiency.

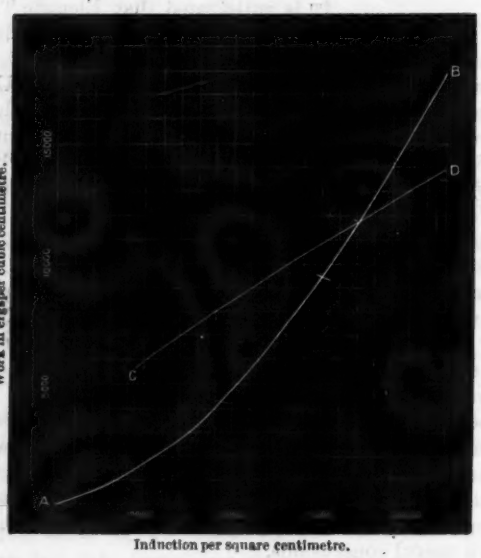



FIG. 150.

We have said that there are three sources of waste—first, the energy spent in the conductors due to their having some resistance; secondly, the energy expended in continually changing the direction of the magnetism in the rotating core; and, thirdly, the energy of feeble parasitic currents generated in both conductors and core. The energy dissipated in the armature due to the first cause can be calculated from the resistance of the winding from brush to brush and the total current flowing. The loss from the third cause cannot be very readily calculated, but may be rendered almost negligible by adopting the precautions insisted on in Section VII., dealing with parasitic currents. The points necessary to be observed in construction, so that these might be eliminated as much as possible, were then clearly stated; briefly, the core has to be supported so that no part of the supports is subject to inductive action, the core has to be laminated in planes perpendicular to the direction of induction, and parallel to the direction of motion, and the conductors have to be divided and grouped in certain ways in the winding. If these rules are carefully attended to, the loss due to parasitic currents becomes unimportant; not so, however, is the second source of loss, which we are about to consider.

In carrying a piece of iron through a cycle of magnetisation, there is expended in the operation a definite amount of energy depending on the induction and on the character of the iron. Starting with a piece of iron magnetised in one direction, a cycle defines the operation by which the induction is reduced to zero, reversed and brought up to the same strength in the opposite dirction, again reduced to zero, and finally brought up to its first degree of induction. Imagining for a moment that every molecule of iron is a small magnet, it will be readily perceived that, since the axial direction of the molecules is governed by the direction of induction, in one complete cycle each molecule must rotate once with reference to the mass of which it forms a unit. In producing this rotation involved by the magnetic cycle, work is performed either in overcoming a kind of frictional resistance, as has been hitherto assumed, or in overcoming the magnetic forces which the molecular magnets exert upon each other, as has been suggested recently by Prof. Ewing. The energy expended in carrying annealed soft iron wire through cycles such as described, has been carefully determined by this experimenter, a curve showing the results being given in fig. 150. The induction per square centimetre is plotted as abscissæ, and the energy in ergs required to carry a cubic centimetre of soft iron through a complete cycle at different inductions is measured by ordinates. The resulting curve, A, B, shows that the energy increases at a somewhat greater rate than the induction. The use of the curve, C, D, will be seen hereafter.

In applying these results to the case of a revolving armature core, it has been assumed that, in causing the molecules to rotate, there is performed the same amount of work as given above, although in the former case the molecular rotation is caused by varying the intensity of magnetisation, carrying it through zero and reversing its direction, while, in the case of the armature, it is produced by change in direction without change in intensity. The assumption seems a fair one, though it must be remembered that the energy required is reduced somewhat in the presence of vibration, and that consequently the work, in a moving armature core, might be expected to be under the amount here given. Again, Ewing's experiments were performed by making the changes very slowly, and, in dealing with armatures, the farther assumption has to be made that the work done per cycle is the same, whether the changes are slow or rapid. Some idea of the power wasted in reversing the magnetism of the armature may now be obtained. Taking a direct current two-pole 300-light machine having a ring core, say, of 33 centimetres diameter, with an internal opening of 23 centimetres and a length of 28 centimetres, the same amount of soft iron contained in such a core is, allowing for insulation between the plates, 11,000 cubic centimetres. The induction is, say, 17,000, and from the curve we get the ergs expended per cycle per cubic centimetre as 11,800. The speed of the armature being 900 revolutions per minute, this gives us $11{,}000 \times \frac{900}{60} \times 11{,}800$ ergs per second = 195 watts. There would probably be expended in heating the armature coils of such a machine 780 watts, the heat generated in magnetising and demagnetising the iron core constituting, therefore, about 20 per cent. of the total heat generated in the armature. In alternating current machines, where the number of cycles per second is rather more than six times as many, it will be seen that the work expended on changing the direction of the magnetism becomes of great importance relatively to the other sources of waste.

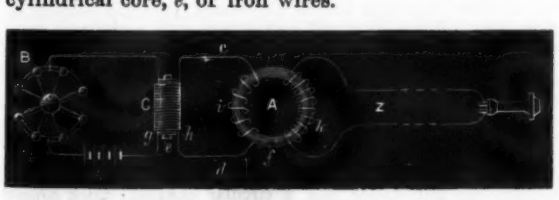
In this article, we have seen that the amount of heat generated in the armature can be calculated with a fair degree of accuracy. In our next article, we have to determine the amount of cooling surface it is necessary to allow in order that the heat generated may be got rid of without exceeding the specified limit of temperature.

(*To be continued.*)

## TELEPHONE INDUCTION COILS.

IN a recent number of the *Electrical Engineer* (New York), a system of telephony devised by Mr. T. D. Lockwood is described. The employment of closed circuit induction coils in telephony involves certain considerations which do not appear at first sight. It is, of course, comparatively easy to operate electric light transformers by means of reversals of the primary current, because, since the secondary currents to be evolved need have no special form, character, or quality, these reversals may readily be produced by using an alternating dynamo as a source and by sending its currents unrectified through the primary helix. But no such procedure is possible in telephony, for the voice currents developed in the secondary circuit of the induction coil, which are to traverse the line and reproduce speech at the distant station, must, so to speak, be an electrical copy of the variations of the sound waves initiating them, and also of the sound waves they are to reproduce. Up to the present time, however, it has not been found practicable to produce reversals in the primary circuit of transmitting telephone induction coils, and in all such instruments which have gone into use the change which the operation of the transmitter effects in the primary circuit is not a reversal of current, and hence cannot result in a reversal of magnetism with its inherently-consequent zero moment. It is not even a succession of absolute cessations and emissions of current, as in the make and break of the Ruhmkorff induction coils. The change which is effected by such operation is the variation of current strength, tending to produce a variation of magnetic intensity in the core, which, if produced, results in corresponding magneto-electric currents in the secondary helix and line; but the magnetism of an iron ring core once magnetised does not greatly vary when simple changes only are made in the strength of the magnetising current. Thus, while it tends to advantage to employ induction coils having closed magnetic circuit cores, such a procedure demands also a practical method of producing reversals in the primary circuit of the induction coil, and it is to accomplish the latter object that Mr. Lockwood has designed the system we are about to describe.

The method employed is illustrated diagrammatically in the fig. Here B is a multiple-contact microphone, which is placed in the circuit of a battery, *b*, in which also is serially included the primary conductor, *g*, of the induction coil, C. This circuit may be termed the "local circuit." The secondary conductor, *h*, of this coil has the same number of convolutions, and is of the same size wire, and both are, as usual, wound upon a cylindrical core, *e*, of iron wires.




The induction coil, A, has a continuous core, *f*, of soft iron, and constituting a closed magnetic circuit. This has a primary conductor, *i*, the same size and length as that employed in the two helices of the first coil, which is joined up in circuit with the secondary conductor, *h*, of induction coil, C, and the closed circuit so constituted may be termed the "intermediate circuit." Thus alternating currents generated in conductor, *h*, inductively by changes of current in conductor, *g*, will be of like character with such changes, and will of necessity circulate in and through the primary conductor, *i*, of induction coil, A. The resistance of the conductors, *g* and *h* and *i*, is low, being but a fraction of an ohm.

The secondary conductor, *k*, of coil A, is of fine wire, for the purpose of securing a great many convolutions, it being required not only to transfer electrical energy from the reversals circulating in *i* to the secondary conductor, *k*, but to raise the potential. The secondary, *k*, of the induction coil, A, is connected with the wires of the main telephone circuit, Z, leading to the distant station and telephone receiver. In actual practice Mr. Lockwood winds the primary coil in alternate sections, spaces being left between each for similar sections of the secondary winding. The advantage of this method of winding is that the magnetisation is thereby distributed uniformly, and is enabled to act equally upon all parts of the core.

It will be observed that the function of the first induction coil is to develop alternating currents in the intermediate circuit without raising the potential of such currents. If the potential in this circuit were to be raised, it would be necessary to multiply the convolutions of both the helices included in it, with a consequent increase in cost, in resistance, and in waste of energy. Furthermore, it is of great importance to keep down the resistance of this intermediate circuit, for the reason that in telephony self-induction is a potent factor in opposing the proper operation of the current, and the self-induction of any circuit of which coils or helices form a part is mainly dependent upon the number of their convolutions. Hence, there is special utility in employing a few convolutions of thick wire instead of a greater number of convolutions of thinner wire in the intermediate circuit.

We witnessed some experiments a few years ago with coils constructed like transformers, to be used for translation purposes from a single wire to a double wire system, but the *speaking* results were extremely poor, though the ringing of the call bells (on the magneto principle) was all that could be desired. On the other hand, it was found that when ordinary induction coils were used as translators, the speaking was excellent, but the magneto bells would not ring. Mr. Lockwood's method seems well adapted to make both speaking and ringing good, but the use of two induction coils would appear likely to involve a loss of power, and it seems open to doubt whether any directly beneficial result is practically found to result from the new arrangement. We observe that the *Electrical Engineer* is silent with reference to the practical working of this method.

## BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.—LEEDS, 1890.

### ON THE SPECIFIC RESISTANCE OF COPPER.

By T. C. FITZPATRICK.

(*Read in Section A, September 9th, 1890, in conjunction with the report of the Committee on Electrical Standards.*)

ALL the values given in tables for the specific resistance of the metals are directly or indirectly obtained from the values given by Matthiessen in his series of papers published in the "Transactions of the Royal Society" for the years 1860—1864, and in the reports of the British Association for the same years.

In the "Transactions"* for the year 1860 is a paper by Matthiessen on the conductivity of pure copper and on the effects of impurities. No alloy of copper has as high a conductivity as the pure metal. His results are expressed in terms of the conductivity of a hard-drawn silver wire (100 at 0°). He gives the following values for samples of copper carefully prepared by himself:—

| | | |
|---|---|---|
| (1) | 93·00 at 18·6° | Giving a mean value of 93·08 at 18·9° as the conductivity of pure copper. |
| (2) | 93·46 „ 20·2° | |
| (3) | 93·02 „ 18·4° | |
| (4) | 92·76 „ 19·3° | |
| (5) | 92·99 „ 17·5° | |

Numbers are given showing the effect on the conductivity of small quantities of oxide, and he states that he found it necessary to pass hydrogen through the molten metal for some time for entire reduction. In the "Transactions" for 1862 Dr. Matthiessen has a paper on the influence of temperature on the conductivity of metals. He again expresses his results in terms of a hard-drawn silver wire.

On page 8 will be found the results of his experiments on copper: the lowest temperature at which measurements were made was 12° or 16°; he there shows how the results for pure copper measured at 18° may be reduced to 0° C.; but no measurement was actually made at 0° for any of the metals experimented with.

* "Phil. Trans.," 1860, p. 85.

He expresses the influence of temperature on a hard-drawn copper wire; the mean result of a number of determinations by the equation

$$\lambda = 100 - \cdot38701\, t + \cdot0009009\, t^2$$

where 100 is the conductivity of copper at 0° C., so that a hard-drawn silver and copper wire have the same conductivity at 0° C.

The values obtained by comparison with a hard-drawn silver wire are then largely the source of the tables of specific resistances; but at the end of his appendix to the report of the Electrical Standards Committee for 1864, Matthiesser gives values for hard-drawn silver and copper wires in terms of the new B.A. unit; expressed as the resistance of a wire one metre long, weighing one gramme.

These values are:—

| | | | |
|---|---|---|---|
| Copper | ... | ... | ·1469 |
| Silver | ... | ... | ·1682 |

The same table of values is given in the *Philosophical Magazine* for 1865, where also is given a table of specific resistances for wires 1 metre long and 1 millimetre diameter expressed in terms of the B.A. units, calculated from the value of the known conducting power of the gold-silver alloy in terms of hard-drawn silver, and also in terms of the B.A. unit.

The values thus obtained do not agree at all well with the results calculated for the resistances of the gramme metre by the specific gravities of the elements furnished by tables.

Thus:—

| | | | | | |
|---|---|---|---|---|---|
| Silver | ... | ... | ·02048 | ... | ·02603 |
| Copper | ... | ... | ·02090 | ... | ·02104 |

He states that he omitted to determine the specific gravity of the copper used in his experiments; he probably would not have obtained any very adequate results, and the weight of copper he used varied from 1·5 to 4 grammes.

The accuracy of Matthiessen's results seems to depend, therefore, on the accuracy of his determination of the resistance in terms of the B.A. unit of a hard-drawn silver wire; in considering, therefore, the question of the preparation of samples of copper of higher conductivities than Matthiessen obtained, it may be suggested that the cause of the difference is not explained by the fact that Matthiessen did not prepare pure copper, but by the error in the value of the standard with which the comparison was made.

I have, therefore, made a series of experiments on the resistance of pure silver wires; and, as a general result, have obtained a value identical with that of Matthiessen; the difference is not due, therefore, to an error in the standard employed, as far as my experiments go.

Matthiessen does not give anywhere the details of his measurements of the specific resistances of the metals in terms of the B.A. unit; in the B.A. report he simply mentions that an approximate table is subjoined, not even stating the fact that the values are for a temperature of 0° C. I conclude, therefore, that these values are calculated out from the former, of which an account is given in the same B.A. report, and which were performed at a temperature of 20° C.

I have, therefore, on this account, as well as for other reasons stated later, made my measurements at the temperature of the air, and believe that as his values were reduced by a temperature coefficient to values at 0° C.; I shall, by using the same temperature coefficient, and raising his value to near that for 20° C., obtain results directly comparable with Matthiessen's direct measurements.

For the measurement of the resistance of the specimens of wire a Wheatstone's bridge arrangement was employed, two of the arms of the bridge were formed by a 10 and 1 standard B.A. unit, namely (66 and 6); these were so nearly 10 to 1, that they were taken to be in that ratio.

The third arm was one-third of a B.A. unit, and in the fourth arm was the wire to be measured, this was stretched on a flat board, and soldered at the ends to copper plates, to which connecting wires were also soldered; the length of wire used was generally a little less than two metres, and the wires were, approximately, No. 18 B.W.G. The board had scales screwed to it at the two ends; the board and wire were placed in a long bath made of zinc, and filled with paraffin; wires which were left in the bath for some days, and, in more than one case, several weeks, were not found to have been at all acted on by the oil.

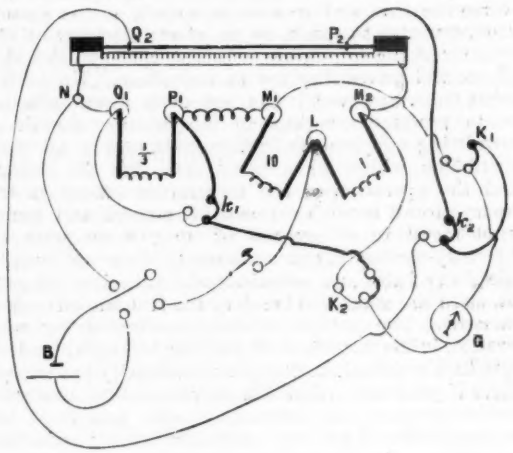
One end of the wire, $P_2$, $Q_2$, was connected by a binding screw through an adjustable resistance, $r$, ($\frac{1}{4}$ metre of copper wire) to the mercury cup, $Q_1$, in which was one of the legs of the one-third coil, and also to a reversing key in the battery circuit.

The $\frac{1}{3}$rd and the 10 were connected up together through an adjustable resistance, $P_1$, $M_1$, one leg of each of the coils 10 and 1 were in the same mercury cup, L; and the other end of the 1 B.A. unit was connected with the other end of the wire, $P_2$, $Q_2$.

A single Leclanché cell was connected up with the reversing key and the fourth point of this key was connected with the mercury cup, L, into which the legs of 10 and 1 dipped. In this circuit there was also a touch key. The galvanometer circuit was always made, and thus there was no thermo-electric effect on meeting the galvanometer circuit. To each of the mercury cups, $Q_1$, $P_1$, $M_1$, $M_2$, were connected with separate binding screws two thick wires, one of which was welded to the copper plate at the bottom of the mercury cup. Each of these latter wires were connected with two way-keys; those in $P_1$ and $Q_1$, to the key, $k_1$; those in $M_1$ to the key, $K_1$; those in $M_2$ to the key, $K_2$.

The base points of the keys, $K_1$ and $K_2$, were connected with a delicate reflecting galvanometer, that employed for the comparison of the standards on the Fleming bridge. The base of the key, $k_1$, was connected with the third point on the key $K_2$, and the third point, on the key, $K_1$, was connected to the base point of a fourth key, $k_2$, the two other points on this key being connected with riders, with which contact can be made with two points on the wire, $P_2$, $Q_2$; the riders had straight edges, and thus their positions on the scales could be easily determined. In performing an experiment, the keys, $K_1$ and $K_2$, were so connected that the mercury cups, and so the ends of the coils, 10 and 1, were in circuit with the galvanometer. The resistance, R, $P_1$, $M_1$, was then varied till, on making the battery circuit, no deflection resulted. The ends of the 10 and 1 were then at the same potential, and as the other ends of these coils were connected with the same pole of the battery, there was the same fall of potential on the two lines.

The keys, $K_1$ and $K_2$, were then reversed, and by the keys, $k_1$ and $k_2$, one end of $\frac{1}{3}$rd coil and one point on the wire, $P_2$, $Q_2$, were connected through the galvanometer, and afterwards the two other ends. The riders were adjusted till there was no deflection of the galvanometer. The length of wire between the two riders had a resistance of $\frac{1}{10}$th that of the $\frac{1}{3}$rd B.A. unit coil.




By means of the series of keys it was easy to repeat the observations and to connect the ends of $\frac{1}{3}$rd coil with the wire. The resistance, R, did not often change during the experiments, as the room was at a constant temperature, any change in R only caused a shifting of the position of the riders. In each experiment, after all the adjustments, the bath was well stirred and everything left for half-an-hour. It was generally found that the riders did not require any adjustment. The battery was reversed and all the coils moved. The latter never caused any effect; sometimes the reversal of the battery caused a shifting of the two riders a millimètre or two in the same direction.

Another reading was taken three or four hours after. The coils $\frac{1}{3}$rd, 10, and 1, were in water baths, and their temperature remained the same for hours together. The temperature of the paraffine bath, of course, was not so constant, it was kept well stirred in, and a thermometer reading to ·2° C. never showed any difference in the temperature at the different ends of the bath when the readings were taken. The thermometer employed was Kew corrected; and the corrections given were verified by recent comparison with a platinum thermometer by Mr. Griffiths.

Since the two standard coils employed were accurately in the ratio of 10 to 1, the accuracy of the resistance measurement depended entirely on the value of the 1/3 B.A. unit. This was first made as nearly as possible 1/3, but it was found that for the size of the wires measured (18 B.W.G.) this was too high a resistance, it had, therefore, to be reduced. For the determination of its value there was cut out in a block of paraffin wax a large central mercury cup and outside this a circular channel; thick copper plates were cut to fit them, and both were well amalgamated. By means of this cup arrangement the three B.A. units (H, G, and flat) were connected up in multiple arc, and by means of stout copper rods the multiple arc arrangement was connected with the mercury cups with the Fleming's bridge, and so compared with the 1/3 B.A. unit, the temperature of the 1/3 being given. The following observations were taken:—

July 12th, 1889:—1/3, (18·4°) + 986·6 (b.w.d.) = M.A. + 24·6 (b.w.d.)

July 22nd, 1889:—1/3, (17·4°) + 986 (b.w.d.) = B.A. + 24·1 (b.w.d.)

Aug. 26th, 1890:—1/3, (16·8°) + 986·1 (b.w.d.) = M.A. + 23·9 (b.w.d.)

The value of a bridge wire division (b.w.d.) is ·0000498 B.A. units at 15°, and the wire has a temperature coefficient of ·00143.

It is evident from these series of values that the 1/3 has not changed in resistance during the period of the experiments.

This comparison, however, introduced a possible error as the temperature of the bridge wire at the time of experiment was not accurately known, and this is important when nearly the whole of the bridge wire is employed. To eliminate this possible error the 1/3 was compared with four B.A. units in multiple arc. In this

case a large number of bridge wire divisions had to be subtracted from the value of the 1/3, and the whole number of bridge wire divisions entering into the calculation for the values of the 1/3 was largely reduced. The four coils in multiple arc were (F, G, H, and flat):—

Aug. 25th, 1890:—1/3, 16·8° + 157 (b.w.d.) = M.A. + 852·05 (b.w.d.)

Aug. 26th, 1890:—1/3, 16·8° + 157·5 (b.w.d.) = B.A. + 851·9 (b.w.d.)

All the four coils were at the same temperature (16·8). These values are taken from the B.A. Report, 1888.

| | | | | | |
|---|---|---|---|---|---|
| Flat | ... | ... | .. | ... | 1·000448 |
| F. | ... | ... | ... | ... | 1·000028 |
| G. | ... | ... | ... | ... | ·99955 |
| H. | ... | ... | ... | ... | ·99969 |

These give for the two multiple arc arrangements the values ·33330 and ·24998. The connecting rods had a resistance of ·00042, and these gave for the value of the 1/3 at 16·8° ·28537. The temperature coefficient for the coil is ·0001 per 1° C.

To measure the lengths of the wires two microscopes with scales and verniers reading to ·1 of a millimetre were set up and firmly clamped in position; the distance between them was determined by means of the beam compass and the aid of a third microscope; the distance between this and the other two being directly read off on the beam compass for set positions of the verniers. The wires were cut with a fine fret saw at the points corresponding to the position of the riders in the resistance measurements. Before weighing the wires were carefully cleaned with methylated spirits, the balance employed was the one used by Mr. Glazebrook for our determination of the specific resistance of mercury, the weights were balanced against one another, and in all cases double weighings were taken.

The specific gravity of most of the wires was measured, for this purpose distilled water was boiled and cooled rapidly, the coil of wire immersed and the beaker and its contents placed under the receiver of an air pump, which was connected up with a water pump, this was left running for two or three hours till all air bubbles had disappeared, the weight of the wire in water was determined, and a second reading taken some hours later; as the weight of wire used was from 16 to 20 grammes, fairly accurate values for the specific gravity of the several wires ought to have been obtained, and thus the value for each wire in terms of the B.A. unit for the resistance to conduction between the opposite faces of a cube of the material was found.

*Resistance of Various Specimens of Wire.*

| Wire. | Date. | Resistance of a wire such that 1 metre weighs 1 gramme at 18° C. | | Specific gravity. | Specific resistance per cc. at 18° C. | |
|---|---|---|---|---|---|---|
| | | Hard drwn | Annealed. | | Hard drwn | Annealed |
| I. | July 22, '89 | ... | 1549 | 8·86 | ... | 1743 |
| | Nov. 6, '89 | ... | 1550 | 8·87 | ... | 1745 |
| II. | July 22, '89 | ... | 1545 | 8·88 | ... | 1741 |
| | Dec. 2, '89 | ... | 1546 | 8·89 | ... | 1742 |
| III. | Dec. 3, '89 | ... | 1713 | 8·87 | ... | 1922 |
| IV. | July 10, '89 | 1578 | ... | 8·89 | 1776 | ... |
| | Aug. 1, '89 | 1578 | ... | 8·89 | 1776 | ... |
| IV'. | Nov. 1, '89 | ... | 1511 | 8·885 | ... | 1724 |
| V. | July 31, '89 | 1573 | ... | 8·89 | 1770 | ... |
| | Oct. 30, '89 | 1572 | ... | 8·89 | 1770 | ... |
| V'. | July 20, '89 | ... | 1526 | 8·89 | ... | 1712 |
| | Aug. 2, '89 | ... | 1526 | 8·89 | ... | 1713 |
| | Aug. 8, '89 | ... | 1527 | 8·89 | ... | 1716 |
| VI. | Aug. 10, '89 | 1546 | ... | 8·94 | 1730 | ... |
| | Oct. 18, '89 | 1549 | ... | 8·94 | 1732 | ... |
| | July 10, '90 | 1549 | ... | 8·94 | 1731 | ... |
| | July 14, '90 | 1548 | ... | not observd | ... | ... |
| VI'. | Aug. 8, '89 | ... | 1508 | 8·94 | ... | 1688 |
| | Oct. 11, '89 | ... | 1509 | 8·94 | ... | 1688 |
| VII. | Nov. 4, '89 | 1543 | ... | 8·946 | 1724 | ... |
| | July 15, '90 | 1543 | ... | ... | ... | ... |
| VIII. | Oct. 23, '89 | 1700 | ... | 8·95 | 1903 | ... |
| | Oct. 28, '89 | 1702 | ... | ... | ... | ... |
| IX. | Aug. 5, '90 | 1572 | ... | 8·90 | 1766 | ... |
| | Aug. 18, '90 | 1572 | ... | 8·90 | 1766 | ... |
| X. | Aug. 5, '90 | 1573 | ... | 8·91 | 1767 | ... |
| | Aug. 26, '90 | 1569 | ... | 8·92 | 1751 | .. |
| XI. | Aug. 27, '90 | 1569 | ... | 8·93 | 1750 | ... |
| Matthiessen's value reduced to 18°, using his own coefficient | | 1571 | ... | not given | 1766·6 | As calculated by Fleming Jenkin & Fitzpatrick |

The first object of these experiments was to test directly in comparison with the B.A. standards samples of copper wire of high conductivities, with the view of comparing them with Matthiessen's standard. Application was therefore made to several firms for high conductivity copper wires, for which my thanks are due to those who sent samples.

A table of results is subjoined, the results for all the specimens tested are given, and they show the variation in resistance of high conductivity wires.

IV. and IV'. are the same copper, but IV. is hard drawn, IV.' is annealed; they were measured just as they were sent from the manufacturers; the same is true of V. and V.', VI. and VI'.

It will be noticed that VI. and VI.[1], which are of considerably less resistance than the other wires, are of higher specific gravity; the firm that sent them thus wrote of them, "it is only occasionally we come across copper as high as this or high enough to be called the highest (in conductivity) we can produce. This copper has been produced electrolytically by our ordinary process." How this copper was treated after electro-deposition I do not know, I am inclined to think from my own experience that this difference in density is due rather to the condition of the copper, than to its relative purity. Matthiessen found that very small quantities of impurities reduced the conductivity 20 or 30 per cent. and a sufficient amount of impurities to cause this decrease in density from 8·94 to 8·90, must make a larger increase in the resistance of the copper.

The temperature coefficient is stated to be different for various specimens of metal, according to their purity; Matthiessen himself seems to have been of this opinion, but the mere difference in density of the metal might be expected to effect the alteration of conductivity with the same change in temperature.

I have not been able to find any experiments bearing on this question. It is quite easy to obtain samples of wire of different density by varying the process of drawing, and the temperature coefficients of such wires might be found to be different.

Comparing V. and V.' with VI. and VI.' it is seen that with this increase of density there is a distinct diminution in the effect of annealing.

IV. − IV.' = ·00677
V. − V.' = ·00577
VI. − VI.' = ·004

I thought it might be possible that VI.' was not completely annealed, so, for a direct comparison, two specimens of VI., which had been measured hard drawn on July 10th and 14th, 1890, were annealed; for this purpose a flat copper vessel was made of about 2 cm. height and 18 in diameter, with a closely fitting lid; the wire was packed in this between sheet asbestos, which had been previously heated up; the vessel was filled up with lampblack, the vessel was heated over a big bunsen burner and gradually cooled, the process generally took about 24 hours, the wire was found not to be oxidised at all after the process was over.

| Wire. | Hard-drawn | Annealed. | Difference. |
|---|---|---|---|
| I. | 1549 | 1510 | ·0039 |
| II. | 1548 | 1509 | ·0039 |

The difference Matthiessen obtained was ·0038.

The above method of annealing was found very effective. Silver wires, which on annealing decrease 10 per cent. in resistance, gave the same value in a second annealing as they did on the first occasion.

Wire VII. was a wire sent me by Mr. H. A. Taylor, and had to be drawn down before it could be measured; another piece of the same wire drawn down on a different occasion, gave the same value; this wire has the lowest resistance of any I have obtained; it has, too, the highest specific gravity; Mr. Taylor says of it, "That it has a higher temperature coefficient than that given by Matthiessen."

VIII. was a sample of wire obtained from Germany, and said to be electrolytically prepared; its high resistance is, I think, due to the presence of oxide, and I fused some of it up in hydrogen, and when measured partially annealed it gave the value ·1566 at 18° for the wire 1 metre weighing one gramme.

IX., X. and XI. are wires of my own preparation. Pure copper was prepared electrolytically by Messrs. Sutton, of Norwich, and supplied me in thin sheet, and this was fused down in porcelain tubes of 18 centimetres in length and 1 centimetre in diameter; the tube was fitted up in a small furnace made of sheet iron and lined with ganister; this was heated readily by a blast flame led in at the bottom; some difficulty was experienced in obtaining the copper in a solid cylinder; in the early experiments hydrogen was passed into the tube whilst the copper was being fused and was made to bubble through the molten copper; on breaking the tube, the copper was found to be full of small holes; the copper had absorbed the hydrogen at the high temperature and given it off again on cooling; on another occasion the copper was fused down in hydrogen and the tube was connected with a water pump and exhausted, and the copper allowed to cool in a vacuum; this gave a more continuous cylinder. It was found best to fuse the copper under borax, it having been previously reduced; a good cylinder of the metal was thus obtained.

I was unfortunately not able to draw down the copper for myself; this was very kindly done for me by Messrs. Smith, of Halifax, and Messrs. Johnson and Matthey. The porcelain tubes had been prepared of such a size that the cylinder of copper could be drawn without further heating; the copper, therefore, was not fused after it left my hands.

Two sheets of the electrolytically prepared copper were used

down on different days, and one was sent to Messrs. Smith to be drawn, and the other to Messrs. Johnson and Matthey.

Wires IX. were drawn by Messrs. Smith, wires X. by Messrs. Johnson and Matthey.

Wire XI. was drawn by Messrs. Johnson and Matthey from a sample of copper which I prepared by electrolysis, from a pure solution of copper sulphate; the copper was deposited on a plate of copper, which had had its surface rubbed over with graphite; by this means the deposited copper was easily stripped off the plate, the other plate was of platinum, after a time the solution was changed; the deposition was very slow, as it was thought that there would be less liklihood of copper sulphate getting in between the layers of copper.

The deposit was boiled with dilute sulphuric acid and then in water, and was afterwards fused down as above dercribed.

Wires IX. were measured as received, this accounts for the close agreement between the two determinations. Wires X. and XI. I had to draw down further to measure them on my bridge.

Wires X. (2.) and XI. were drawn down with great care and not so much as X. (1.)

Below is a table of the measurements made for the determination of their specific resistances.

| Wire. | Value of 1/s. | Temp | Weight of wire. | Length of wire for determination of resistance. | Length cut and weighed. | Resistance of gramme per metre. | |
|---|---|---|---|---|---|---|---|
| IX. (1.) | ·28547 | 17·9° | 20·388 | 192·1 | 192·5 | 1574 | 18·3° |
| „ (2.) | ·28541 | 17·4° | 20·153 | 192·4 | 190·45 | 1569 | 17·5° |
| X. (1.) | ·28550 | 18·2° | 19·708 | 189·3 | 188·8 | 1577 | 18·6° |
| „ (2.) | ·28536 | 16·8° | 20·252 | 192·39 | 192·34 | 1561 | 17·1° |
| XI. | ·28535 | 16·7° | 20·262 | 192·11 | 192·51 | 1563 | 17·2° |

These values reduced to a common temperature of 18° are:—

| | | | |
|---|---|---|---|
| IX. (1) | ... | ·1572 | |
| IX. (2) | ... | ·1572 | Mean value |
| X. (1) | ... | ·1573 | ·1571 |
| X. (2) | ... | ·1569 | B.A. units. |
| XI. | ... | ·1569 | |

Thus ·1571 B.A. units is the resistance of a metre of hard-drawn copper wire at 18° weighing 1 gramme.

Matthiessen in the B.A. Report * gives as the resistance of a gramme metre at 0° ·1469 B.A. units.

I have calculated from this the value at 18°, using the temperature coefficient that he gives in his paper on the influence of temperature on the conducting power of metals. I have taken no account of the terms in $t^2$ as they practically cancel one another.

$$R.\ (\text{at } 18°) \quad 18° = R°.\ (1 + ·0038701\ t)$$

$$R.\ 18° = ·1571.$$

This is the same value that I have obtained as the mean of my own observations.

All my observations were taken at the temperature of the room, and in the table above, the values for the different wires are given at the observed temperature, and then all reduced to a common temperature of 18° C. Most observations of this character are taken at the temperature of 0° C., but on the whole it seemed more satisfactory to work at the temperature of the room. In the comparison of the B.A. units I have found that with a difference of temperature between coils which are connected by thick pieces of copper there is always conduction of heat, and it is impossible to tell accurately what is the real temperature of the coils.

My observations were made in the B.A. room at the Cavendish Laboratory, which has a north aspect, and often the temperature does not alter more than a few tenths of a degree, whilst the temperature of the coil baths often remains perfectly steady for several consecutive days. I cannot find any observations of Matthiessen's at 0° C; certainly his observations on copper were made at 18°, and, consequently, if the value given by him at 0° C. has been obtained by the use of a temperature coefficient, my value might be expected to agree with his at 18°, the temperature of his observation, supposing the samples of copper of the same character.

Matthiessen's results are given in terms of a gramme per metre, also for wires of metre length and 1 mm. in diameter.

In a paper in the *Philosophical Magazine*, Matthiessen gives us the value for hard-drawn copper in these terms as,

·02104 B.A.

From his value for the Gramme metre, using the sp. gravity 8·95 given by tables, the same quantity was calculated but gave the result ·0209; in a note added, he states that had he used the sp. gravity 8·91, his results would have been more nearly alike; but a sp. gravity 8·90, I find, would give an almost identical value.

This would show then that Matthiessen's own table calculated for values obtained by comparisen with hard-drawn silver is accurate; I have tested silver wires, but have not had time to draw up the results in tabular form; and I obtained an almost identical value for hard-drawn silver wire, as supplied me from Messrs. Johnson and Matthey, as is given by Matthiessen for the resistance of a gramme per metre.

It will be observed that wires IX. have the specific gravity 8·90, and give a value in terms of B.A. units for a cubic centimetre of the material identical with Matthiessen's value; this value is not given directly by Matthiessen, but is calculated from his results by Fleming Jenkin and given in his table in his book "Electricity and Magnetism," it is 1,652. I have calculated it from Matthiessen's value given in the *Philosophical Magazine*, and get the number 1,653. Using the same temperature coefficient as before, the resistance of a cubic centimetre of hard-drawn copper is 1766·6.

On comparing the values for wires IX., X. and XI. in these terms, the results do not agree so well together as when expressed in terms of the gramme metre; there is a corresponding difference in the values of the specific gravities, these latter have been very carefully determined, repeated with the results given.

Wires, therefore, of the same resistance expressed for grammes per metre may give a very different result, when expressed as per cubic centimetre; attention has been drawn to this fact in the discussion on the Elmore copper in the *Electrician**. M. Roux, of Paris, in a letter gives the following table for high conductivity wire, from a paper of M. Hospitalier in *L'Electricien*, 1887; this paper I have, unfortunately, not been able to see.

| | | | |
|---|---|---|---|
| Density ... ... ... | 8·897 | 9·32 | 9·6 |
| Conductivity equal volume | 102·4 | 106·7 | 110·8 |
| Conductivity equal weight | 101·7 | 101·2 | 101·6 |

What is 100 in the conductivity units is not expressed. M. Roux thinks that the former is the more rational method of expressing the result, i.e., for one of equal volume.

Matthiessen expressed all his results in terms of equal weight, justifying it by the greater accuracy obtainable when working with small weights of wires. Small errors in the value of the specific gravity are easily made, and cause a similar error in the result for equal volumes of different wires; unless working with long lengths of thick wire the weight of the wire is small, and the weight of the water displaced cannot be determined within ·5 to 1 milligramme, and that only with care: this error in ·5 of a gramme means only an accuracy of 1 in 500. The values given in my table are probably correct to 1 in 1,500 or 1 in 2,000, as the weight of water displaced was in all cases over 2 grammes. Results, therefore, for resistances of wires of equal weight are the most trustworthy and, I think, also the most satisfactory if used to express the resistance of a material and not of any given wire.

Wires X. (1) and X. (2) are of the same copper, but drawn down separately X. (1) was beginning to fray, and another specimen of the same copper drawn down still further had on this account to be rejected; this has affected the resistance value expressed in both ways. Thus

| | | | | |
|---|---|---|---|---|
| X. (1) | ... | ·1573 | ... | 1767 |
| X. (2) | ... | 1569 | ... | 1751 |

but much more so when expressed for equal volumes. In both the copper is of the same quality.

It will be noticed that with increase of specific gravity there is a decrease of resistance, even when the results are expressed for wires of equal weight; the resistance diminishes, therefore, more rapidly than the density increases. Wires, therefore, of the same quality may, in consequence of a difference in drawing, have a different density, and so the results expressed in terms of equal volume will differ considerably; while those for equal weight are the same, or approximately so.

The values obtained for IX., X. and XI. are so nearly identical, that it is not unfair to conclude that they are samples of pure copper; their value is identical with that obtained by Matthiessen at, I believe, the same temperature. The greater difference obtained at 0° C. between Matthiessen's value and samples of copper tested now at that temperature, is probably due to the fact that Matthiessen's value was not determined at 0°, but reduced in value for that temperature from observations, as stated above, at about 26° C.

The higher conductivity or less resistance for the two samples given in the table is due not to increased purity in the preparation of the copper, but in the difference in the process of preparation, whereby a sample of greater density is obtained than results from the working up of small quantities of copper in the laboratory.

A sample of copper has been prepared by chemical means with the the help of my friend, Mr. Skinner, but has not yet been measured.

The discussion on this paper and others will be given in a later issue.

* B.A. Report, 1864, or *Phil. Mag.*

## NOTES ON THE VULCANISATION AND DECAY OF INDIA-RUBBER.

By WILLIAM THOMSON, F.R.S.Ed., F.C.S.

*(Read before Section B., September 10th, 1890.)*

UNDER ordinary conditions India-rubber for vulcanising is usually mixed with sulphur and heated to a high temperature, when chemical combination takes place between the sulphur and the

* *Electrician*, December 7th, 1888.

rubber, producing a much more valuable compound for ordinary purposes than unvulcanised rubber, the former remaining plastic at very low temperatures and firm at high temperatures, whilst the latter becomes hard and quite soft respectively at those temperatures.

In making cloth for waterproof garments another method is employed for vulcanising the rubber, viz., by wetting its surface with a mixture of somewhere about 5 to 10 parts of chloride of sulphur dissolved in 100 parts of bi-sulphide of carbon and then heating the fabric gently to evaporate away the excess of these substances: the rubber-covered cloth cannot be heated to a high temperature like the rubber alone, because the heat would be liable to injure the cotton, silk or wool of the fabric, or destroy or injure the colours.

The bi-sulphide of carbon softens and penetrates the fine layer of rubber, carrying with it the chloride of sulphur dissolved in it, and it is generally supposed that the chloride of sulphur breaks up, the sulphur combining with the rubber, producing vulcanisation, and the chlorine combining with the hydrogen producing hydrochloric acid, which is liberated. This reaction is clearly not the correct one, and it is probable that the reverse is more in accordance with the facts, viz., that the chlorine of the sulphur chloride combines with the rubber, producing vulcanisation, leaving the sulphur in the free state, or only partially in combination with the rubber, because in rubber vulcanised by the cold process I have found free sulphur to be present.

From a piece of rubber-covered cloth I separated the rubber and submitted it to analysis by mixing it thoroughly in small pieces with pure sodium carbonate and igniting, then dissolving the whole in water and adding to it peroxide of hydrogen previously treated with excess of barium chloride (to separate sulphuric acid or sulphates). The peroxide ensures the convertion of the lower oxides of sulphur into sulphuric acid, whilst the excess of barium chlorides precipitates the sulphuric acid in the solution which is then weighed as barium sulphate.

Another portion of the made up solution was neutralised and the chlorine present titrated. The rubber, previous to ignition as above described, had been well boiled in water and dried to separate any hydrochloric acid which might be present, but only a faint trace of chlorine compound could be thus separated from the rubber.

The total sulphur present in the rubber amounted to 2·60, and the total chlorine to 6·31 per cent.

The yellow-coloured sulphur proto-chloride is best adapted for vulcanising, because it does not act too strongly upon the rubber, whilst the dark coloured chloride of sulphur containing, as it does, a large quantity of the higher chlorides of sulphur, is liable to render the rubber quite hard by vulcanising it too much. The theory generally adopted to explain this is, that these higher chlorides break up easily, liberating their sulphur which thus combines in greater quantity with the rubber, but my experiments and analyses prove that it is chiefly the chlorine and not the sulphur of the chloride of sulphur which produces the vulcanisation.

*A rubber substitute*, much used at present, is produced by acting on vegetable oils such as rape, linseed, &c., with a mixture of chloride of sulphur and bisulphide of carbon; the oil becomes converted into a solid substance resembling India-rubber to some extent, but being much more brittle. This body is now used in large quantity for mixing with India-rubber for the purpose of cheapening its production. On analyses of some samples of this material I have invariably found that it contained a much greater proportion of chlorine than of sulphur, and this process, therefore, is a vulcanisation by chlorine rather than by sulphur.

Recently I analysed three samples of rubber substitute, the one termed "special," another "spongy" India-rubber substitute, the third being similar to the first in appearance. The first contained of sulphur 3·4 and of chlorine 7·6 per cent.; the second contained of sulphur 4·56 and of chlorine 8·22, and the third 2·67 of sulphur and 7·90 of chlorine per cent.

These rubber substitutes contain considerable quantities of oily matters soluble in ether which I have also found to be chlorine and sulphur compounds of the oils. The first yielded 20·0 per cent., the second 14·3, and the third 11·5 per cent. of these thick oily matters soluble in ether. This oily substance from the first sample contained 2·6 per cent. of sulphur and 6·1 per cent. of chlorine, whilst that from the second contained 2·97 and 6·87 per cent. of sulphur and chlorine respectively.

Some rubber manufacturers regard this oily matter as injurious to the rubber, and reject any substitute which contains any considerable proportion of it. I have found, however, by experiment, that this oily compound, instead of acting injuriously on India-rubber, actually acts as a preservative of it. Some rubber threads were smeared with this oily extract, some with ordinary (unvulcanised) rape oil, and some left untreated; these were put into an incubator at 150° Fahrenheit for a few days, when it was found that the oil-treated rubber was quite soft and rotten, whilst the other two had remained sound. After a few days, more the original rubber thread had become quite rotten, whilst the threads smeared with the oily part of the vulcanised oil remained quite sound.

The first and second samples of rubber substituted were examined for soluble chlorides or hydrochloric acid, by boiling in water, the first gave 0·18 per cent of chlorine soluble in water, and the second 0·05 per cent.

It has been known for some time that copper salts exert a most injurious influence on India-rubber; copper salts are sometimes used in dyeing cloth which are afterwards employed for waterproofing with India-rubber, and it seems quite astonishing what a small quantity of copper is required to harden and destroy the rubber; and the destructive effect of copper is further enhanced if the cloth contains oily matters in which the copper can dissolve. As an example, here is a piece of cloth alleged to have damaged the thin coating of Indiarubber on it. I found it to contain copper, and with a view of demonstrating this point I took one piece in its original condition; to the end of this I pasted a similar piece of the cloth from which the oily and greasy matters had been removed by ether, and to the end of this, again, I pasted another piece of the same cloth from which I had removed both oily and greasy matters and copper; these three pieces joined into one were then coated in the usual way with Indiarubber, and then hung in an incubator at 150° Fahr.; in the course of a few days the rubber on the original cloth had become soft, and it then hardened and became rotten and useless; the second piece from which the greasy matters had been removed then became quite hard and rotten, whilst the part from which both greasy matters and copper had been removed has remained in a perfectly elastic and good condition.

Prof. Dewar observed, accidentally, that metallic copper when heated to the temperature of boiling water in contact with the rubber, exerted a destructive effect upon it. With a view of finding whether this was due to the copper *per se*, or to its power of conducting heat more rapidly to the rubber, I laid a sheet of rubber on a plate of glass and on it placed four clean discs, one of copper, one of platinum, one of zinc, and one of silver; after a few days in an incubator at 150° F., the rubber under the copper had become quite hard, that under the platinum had become slightly affected and hardened at different parts, whilst the rubber under the silver and under the zinc were quite sound and elastic. This would infer that the pure metallic copper had exerted a great oxidising effect on the rubber, the platinum had exerted a slight effect, whilst the zinc and silver respectively had had no injurious influence on it. A still more curious result was this, that the rubber thus hardened by the copper contained no appreciable trace of copper, the copper therefore presumably sets up the oxidising action in the rubber without itself permeating it. I have pleasure in acknowledging the assistance rendered to me in these experiments by my assistant, Mr. Frederick Lewis.

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## A NEW DIRECT READING PHOTOMETER MEASURING FROM UNITY TO INFINITY.

By FREDERICK H. VARLEY, M.I.E.E., F.R.A.S.

(*Read before Section A, September 10th*, 1890.)

THE object I had in view in designing this apparatus was to meet a want that has been felt by electrical engineers and others interested in the measurement of light, namely, a convenient form of apparatus as handy to manage as the usual set of measuring instruments which are provided, so as to take its position along with the voltmeter, the ammeter and the wattmeter.

Incandescent lamps are now made of such generally uniform construction that if we can, with facility, measure the light produced, we can readily deduce, for all practical purposes, the amount of current delivered, and thereby determine the general efficient working of the installation. Or, conversely, if we know the current in watts passing through a glow lamp, we can determine the suitability of the filament for the purpose required, provided we can readily obtain photometric measurements. The conditions imposed are, that the instrument should be portable, have a range from one candle-power to that of the electric arc, that the light to be measured, and that of the standard, should be exactly at the same distance from the screen.

This instrument consists of two discs, each pierced by two semi-ring-shaped windows or apertures. These openings extend to the half circle (180°); both are of the same width, 1 inch broad. The openings in the two discs are placed in reverse positions to one another, so that if one half-ring is opened to its full extent (180°), the other half-ring is entirely closed; or, if the discs are shifted to an intermediate position, both apertures will be opened to an equal extent—namely, 90°.

If, in this position, the discs are rotated, it is obvious that an equal amount of light can pass through both rings, but if the light to be measured is as 1 to 17 C.P., then the angular length of the two apertures must bear a proportionate ratio in order that the two shadows shall be of equal density; and accordingly, one aperture will be open to the extent of 10° for the brighter light, whilst that of the standard light is opened 170°. Instead of dividing the circle into the conventional 360°, I divide the half circle into 2,000 parts, this giving a range from 1 to 1,999, or 2,000 in round numbers. By still farther shifting the discs, this aperture may be entirely closed and read up to infinity. The divisions of the half circle are numbered from left to right and right to left, showing at once the fraction values of the angular extent of the opening or arc, and thereby giving the values of the light.

In order to make the discs turn one upon the other, I have devised a modification of the Furgusson paradox; that is to say, the discs are carried by independent shafts, one of which is hollow to allow the central axis to turn within it; at the end farthest from the discs a cog wheel is fixed to each axis. By means of a sliding link the two wheels can be brought into gear with the axis also provided with cog wheels, each being the same diameter; but one is cut with 100 teeth, whilst the other has 99 teeth. Thus, upon rotating the discs, each revolution of the gearing wheels advances the discs, and so changes the proportion of the openings,

one decreasing whilst the other increases, and *vice versa*; this we can do until the two shadows are of equal density, or approximately so, when the final adjustment can be given by hand. Behind the windows two hollow cones are placed which have their axes directed to a point common to both, but at some distance in front of the discs where the two shadows fall upon the screen. A second or back screen is then placed at the mouth of these cones, over which it fits, and effectively cuts off one light from the other, so that on one side is, say, the electric light, and on the other the standard candle. The light from both passes through axes of their respective cones, and through the discs, and on to the screen upon which the shadow image is cast.

This apparatus, in its present from, has only just been received from Mr. Lege, who has constructed it for us, and Mr. Friese Greene and myself are arranging a series of experiments which, we hope, will prove useful in photography.

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In the course of the discussion, Sir WILLIAM THOMSON stated that it was a question whether integration by sensibility is the same as if continuous light be employed. There is a general idea that they are the same, but the point had not been, so far as he knew, absolutely settled. He had compared sunlight with the light of a candle by means of a pinhole one millimeter in diameter at a distance of a few yards from the paper screen, whilst the candle was at a distance of a few inches; he employed the shadow method. He considered the piece of apparatus exhibited by Mr. Varley to be well devised, and hoped that at the next meeting of the association he would be able to give his results by both methods.

Prof. J. D. EVERETT said that in colour experiments it is assumed that the penumbra method, such as just presented, holds true, because of the consistency of the results.

Prof. G. F. FITZGERALD remarked that it has been calculated that if the energy of all the solar radiations falling upon the earth could be conserved and utilised, each square metre of the earth's surface would afford sustenance to ten individuals, so that—as someone, not an Irishman, had expressed it—"there would be so many people that there would not be room for anyone."

Dr. OLIVER LODGE stated that experiments had been made in Germany showing that a curious physiological effect of flickering light under certain conditions was the production of colour, and that the colour disappeared when the motion was increased.

Mr. FREDERICK VARLEY, in reply to the speakers, said that he was glad to hear from Sir William Thomson the results of his experiments in comparing the light of the sun with a standard candle, and thanked him for the suggestions and encouraging opinions he had expressed. He would point out that the great object he had in view in constructing this apparatus was to obtain a portable and readily worked instrument which could be set up in any room or laboratory. The working of the Bunsen photometer required a room more than a 100 feet long in order to measure a 10,000 candle-power arc light. After speaking of Prof. Ayrton's photometer, he pointed out that by means of the new apparatus, measurements of the electric arc light could be obtained in the space occupied by an ordinary table.

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The following is an illustrated description (for which we are indebted to the *Photographic News*) of the apparatus referred to in the foregoing paper:—

Two discs, perforated by semi-ring-shaped openings, the breadth of which are equal, as shown in fig. 5, are mounted on an axis with

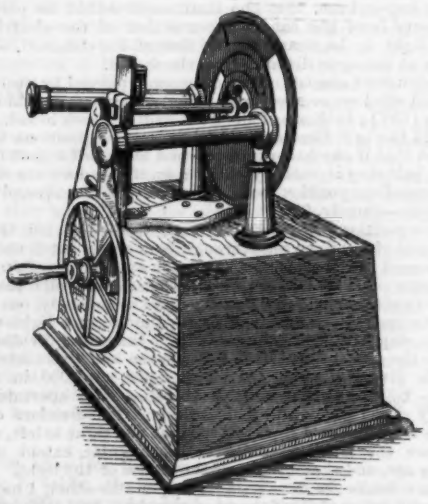


FIG. 4.

their openings reversed, so that when the outer half-ring is fully open (extending to 180°) the inner ring is entirely closed; or if the outer half-ring is open to 90°, then the inner ring will be opened to the same extent, as shown in fig. 6. In that case, when the discs are rotated, two complete circles are formed, through which an equal amount of light will pass. Again, as in fig. 7, the outer ring is nearly open, and the inner one only partially so. As before, two rings are formed upon rotation, but the amount of light which passes through will be unequal, being, in fact, directly proportionate as the extent of the degrees of arc of the openings are to one another. If, say, the outer ring is opened 160°, and the

FIG. 5. FIG. 6. FIG. 7.

inner 20°, in order that the more intense light passing through the inner circle shall balance the standard light passing through the outer, all that has to be done is to read off the respective degrees and write them down in the form of fractions—that is, $\frac{20}{160} = \frac{1}{8}$ from this we ascertain that the light is eight times more intense than the standard. Instead of the conventional division of the circle, we divide the half-circle into 2,000 parts, for the purpose of obtaining a finer or more extended range of reading up to 1,999 times; these divisions, by means of a vernier, can be further subdivided ten times, and read up to 20,000 candles in round numbers.

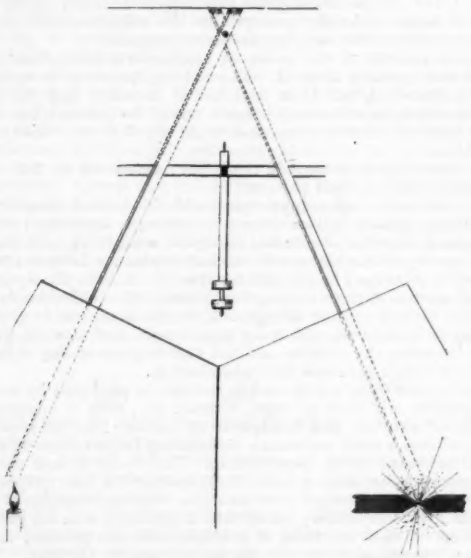


FIG. 8.

The breadth of the semi-ring-shaped windows in this instrument is one inch, and in front of the discs are two equal collimators, one of which projects a disc with a black centre, and the other a corresponding luminous spot. They are regulated so that when the light falling upon the screen from both sources is equal, a uniform disc is obtained; but if one or the other preponderates, a disc with a grey spot, or a grey marginal ring with a bright spot, indicates which of the two sources of light reaching the screen predominates.

In order to regulate this, it is necessary to open one of the windows and close the other until a balance is obtained. This is effected by bringing into play a modification of the well-known Furgusson paradox: the rear disc is carried by the central axis, and the front disc by a long sleeve fitting over it; both the central axis and the sleeve are provided with tooth wheels. Above these is an axis which carries two wheels, one with a hundred teeth, and the other with ninety-nine teeth, which are readily placed in or out of gear by a jointed lever; when in gear they cause the two discs to shift or turn upon each other, and so open or close the windows. It is convenient in some cases to dispense with the collimators, and determine the values of the light by comparison shadows, in which case a T-shaped screen is employed pierced with two holes each a circular inch in diameter, the centres of which are of a distance apart which corresponds with the mean diameter of the circular windows through which the light passes on to the screen. The middle partition forming the T prevents one light from interfering with the other. The apparatus is set in rotation by turning a band wheel, and the windows adjusted until the two shadows balance. The values are read off from the divided scale of 2,000 parts, which is numbered from left to right, and right to left, giving at once the fraction values of the ratios of one aperture to the other.

# A COMPARISON OF A PLATINUM THERMOMETER WITH SOME MERCURY THERMOMETERS AT LOW TEMPERATURES.

By E. H. Griffiths, M.A., Sidney College, Cambridge.

(*Read in Section A, September 9th*, 1890).

The paper describes the mode of constructing an air-tight platinum thermometer for use at low temperatures. The thermometer was graduated by means of the freezing and boiling points of water, and as regards intermediate points Regnault's determinations of the temperature and pressure of aqueous vapour were adopted. The precautions observed in the construction of the apparatus, and in the method of observation, are described. The thermometer was tested by comparison with a number of thermometers standardised at Kew. The curves, showing the result of these determinations, are in remarkably close agreement, and when the observations were sufficiently numerous it appeared possible to calibrate the bore as accurately as by the usual more laborious process. The further advantage of this method is that thermometers can be compared under the conditions in which they are to be used.

In a communication to the Royal Society read on June 19th, 1890, I described a method of constructing and graduating platinum thermometers and gave a table of boiling and freezing points for various substances lying between 100° and 500°, determined by means of these instruments.

Subsequent observations indicate that a slight change appears to be taking place in the readings of these thermometers, I attribute this (1) to alterations in the glass, (2) to presence of moisture in the tube—the asbestos roll on which the spiral was wound being highly hygroscopic. I therefore decided to construct a thermometer in which there should be no contact between the glass and the platinum, and which should be thoroughly dry and hermetically sealed.

I was unable to discover any suitable non-conductor capable of resisting high temperatures; but in Anthracene (melting point 213°) I found a substance suitable in every respect for use at low temperatures. I subjected a sample to severe tests and, up to a temperature of about 130°, found it to be a better insulator than paraffin.

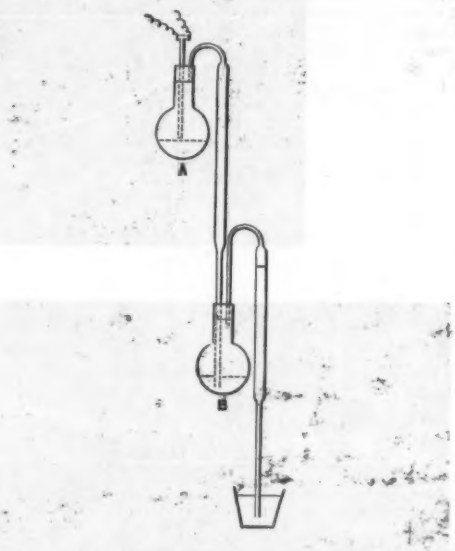
The leads to the coil were constructed of silver, the inner one a rod and the outer a tube. The resistance of these leads was about ·001 ohm and, therefore, any change in the external resistance, caused by change of temperature, might be disregarded. The silver leads approached to within about one inch of the spiral and were connected to it by moderately thick platinum wires; thus a flow of heat from the spiral to the silver was diminished. The wire forming the coil was about fifty-six inches in length and had a diameter of ·005 inch. The spiral was about 2 inches long having a resistance of about 13·5 ohms at 0° C., and the external diameter of the covering tube was about ·3 inch. The ends of the Asbestos roll were made of greater diameter than the portion on which the spiral was wound, and thus there was no glass contact. The tube and contents were heated up to a temperature of several hundred degrees and dried air passed through it for some hours. It was then exhausted and the open end placed under the surface of melted Anthracene, which was allowed to rise until nearly in contact with the coil. When cool, the whole of the thermometer, from the spiral to the upper end (about thirteen inches) was a solid mass, while the spiral and asbestos roll were perfectly dry and in an almost vacuous space. I have taken nearly six hundred observations with this thermometer and cannot detect any signs of change. When the lower part was undergoing rapid changes in temperature, thermo-electric effects showed themselves, but by reversing the battery and galvanometer connections during each reading these effects were eliminated. A low resistance galvanometer was used, and the current, which passed through the thermometer when determining its resistance, did not exceed one hundredth ampère. To illustrate the closeness of the agreement in the results obtained at different times I give the following determinations of the resistance at 100° taken in the usual manner by means of a hypsometer with manometer attached. Full corrections were made in the barometric reading, and the results reduced to lat. 45°.

| Date. | Temperature. | Resistance (after corr. for temp of coils). |
|---|---|---|
| July 26 ... | 100°C. | 18·2029 |
| „ 27 .. | 100°C | 18·2034 |
| August 12 ... | 100°C. | 18·2025 |
| „ 13 ... | 100°C. | 18 2031 |
| | mean | 18·2030 |

The expression for the platinum temperature by this thermometer was $\frac{(R - 13{\cdot}5219}{4{\cdot}6811} \times 100$, again $\frac{R_{100}}{R_0} = 1{\cdot}3462$, almost exactly agreeing with the coefficient of the wire in Mr. Callendar's air thermometer (Phil. Trans. A 1887).

Mr. G. M. Clark, B.A. (Sidney Coll. Cambridge), now joined me in the investigation, and as we proposed to use this thermometer for the calibration and graduation of mercury thermometers between 0° and 100°, we decided to obtain intermediate temperatures by means of Regnault's numbers connecting the temperature and pressure of aqueous vapour. For this purpose we constructed a large iron tank with two plate glass sides, holding about 16 gallons of water, and through two holes bored in the bottom, inserted two barometer tubes, the upper 16 inches of each being within the tank. One of these was used as a standard barometer, and was prepared with great care, the distilled mercury, with which it was filled, having been boiled in the tube for more than 6 hours. The internal diameter of the tube was 14 m.m., and the absence of any meniscus was very marked. If the level of the surface of the water in the tank was below the top of the barometer, and the water warmed, the sublimation of mercury in the vacuous space was observable. The second barometer was made from the same length of tubing as the first, and communicated at its upper extremity with a small flask (A), in which was placed the platinum thermometer.

Distilled water was boiled in vacuo for some hours, to expel all traces of air. The flask and barometer tube were then exhausted by means of an air pump, and the lower end of the tube placed in a flask (B) containing the previously boiled water, which rushed up, filling the tube and flask (A).




The water remaining in (B) was then boiled until this flask and a bent tube passing from it into a bason of mercury, 30 inches beneath, were completely filled with steam, and, on cooling, the height of mercury in the tube enabled us to determine that the pressure on its surface was that of aqueous vapour only. The water in the upper flask was then boiled for many hours, and only allowed to cool occasionally to permit of the water in the lower flask being boiled away. To prevent access of air, the steam was driven off through the mercury. When the water in flask (A) was reduced to about a tablespoonful, the boiling was stopped, and the level of the mercury was raised until it flowed back first into flask (B) and thence into the barometer tube, as flask (A) cooled.

The open end of the barometer tube was then sealed, the flask (B) replaced by a small cup of dry mercury, and the end of the tube opened below the surface. The water remaining on the top of the column was driven back into the flask by pouring hot water over the tube.

During our experiments, water occasionally collected on the mercury, but by means of a concave mirror it was driven back into the flask; the mirror was of course removed sometime before an observation was taken.

The tank, filled with water, was maintained at any required temperature by means of a gas regulator. The lower parts of the barometer tubes were screened by sheets of asbestos, and the two cups were connected by a small siphon. The glass sides of the tank were covered with white paper to prevent radiation, openings were left for observations, during which, the water in the tank was kept in a continual state of agitation by the oscillation of a large paddle driven by a water motor. The paddle, fixed in one corner of the lid, swept across the tank driving the water before it and lifting it at the same time. We have tried several forms of stirrers, and we believe this to be a more effective form than a screw or a plunger.

The difference in the height of the mercury in the two barometer tubes, was ascertained by the kathetometer G. 33, in the Cavendish Laboratory, and by means of it, readings could be taken to ·50 m.m Care was taken to bring both levels horizontal before each observation.

As the co-efficient of expansion of the kathetometer scale was unknown, and the temperature of the room usually about 20°C., we decided to compare it with the standard scale R, whose co-efficient of expansion and scale errors had been determined by the Standards Department of the Board of Trade.[1]

[1] Standard metre, verified June, 1882, designated R in Mr. Chaney's report.

Twenty-one comparisons were made (greatest divergence from the mean ·10 m.m.) and the result was as follows:—300·35 m.m. on kathetometer scale at 20° ($\zeta$=300·35489 of Board of Trade Standard (S.S.) at 0°.

Thus no scale correction was necessary.

The difference (D) of the mercury columns was corrected for temperature, pressure of mercury vapour and latitude and the resulting length denoted by $D_o$: the temperature corresponding to $D_o$ was deduced from the very full table given in Part 3 of Carnelly's "Melting and Boiling Point Tables."

The extremities of the curve at (0° and 190°) having been determined, it was only necessary to get points between 30° and 80°.

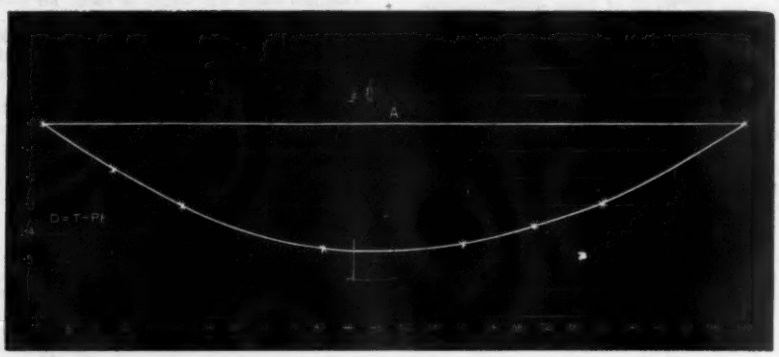
Ninety observations were taken, and although occasional divergences presented themselves, the mean path gives a curve which we believe to be within less than ·02° of the true path at all points. It agrees closely with the curve obtained by Mr. Callendar from the parabola $1·57\left[\left(\frac{t}{100}\right)^2-\frac{t}{100}\right]$, by measuring one tenth of the ordinate along the abscissa.[2]

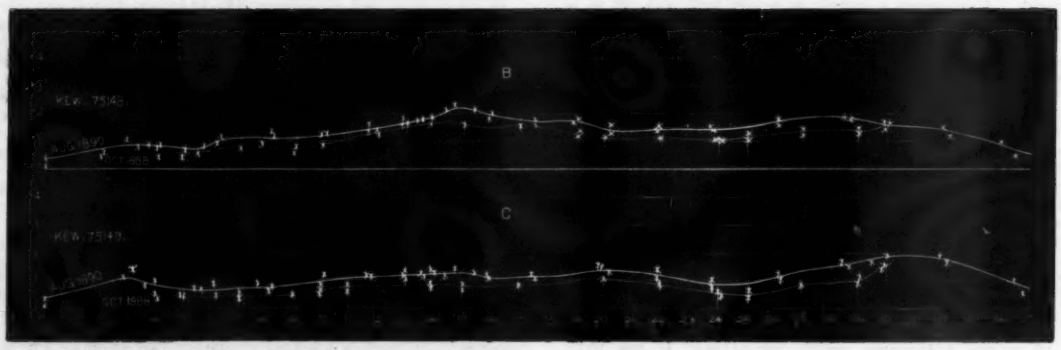
meter temperatures.

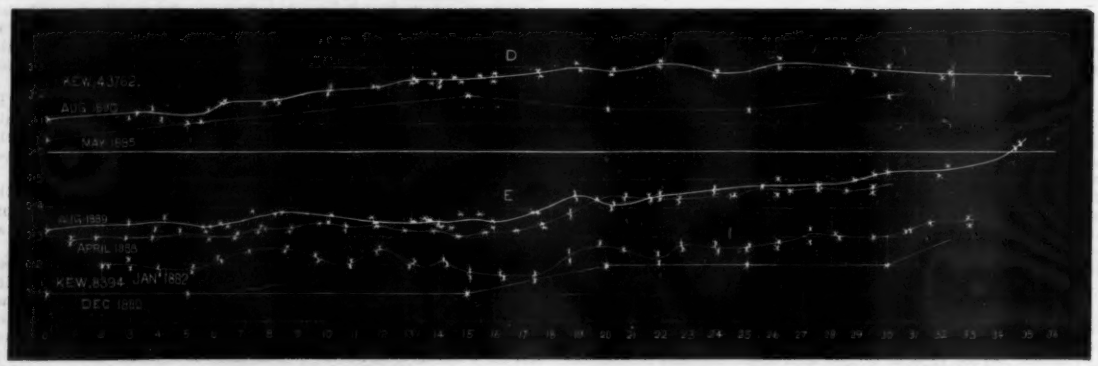
The following equation, however represents its path more accurately.

$y = ·018795t - ·0001991t^2 + ·000,000,111·5t^3$. the curve itself is shown in Chart A.

We proceeded to test our conclusions by comparison with thermometers standardised at Kew; for this purpose a rotating annular ring, through the centre of which the platinum thermometer passed, was inserted in the lid of the tank, in such a manner that the mercury thermometers, fixed in holes bored near its circumference, could successively be brought into the field of view of the kathetometer without any re-adjustment of the telescope; the thermometers were then read by one observer, whilst the platinum resistances were taken by the other. The freezing points were not, however, determined by this method, but by direct immersion in powdered ice, adopting the precautions recommended by Guillaume in his Thermometrie de Précision.




The following curves were then drawn, which indicate the result of the comparison of our platinum thermometer with those standardised at Kew.

| Curve. | Thermometer, Kew No. | Standardised. |
|---|---|---|
| B. | 75148 | October, 1888. |
| C. | 75149 | October, 1888. |
| D. | 43762 | May, 1885. |
| E. | 8394 | Dec., 1880; Jan., 1882; April, 1888. |

All these thermometers were made by Hicks, the first three were kindly placed at our disposal by Mr. R. T. Glazebrook, the last is

[2] It must be remembered that Callendar's difference curve gives the connection between platinum and air-thermometer temperatures, whilst Regnault used a mercury thermometer (M.A.S. XXI.) and thus curve A gives the relation between platinum and mercury thermometer temperature.

one of those referred to by Mr. W. N. Shaw in a communication to the B.A. during the Bath Session, the successive curves of which, then exhibited by him, he has kindly allowed us to copy.

In these diagrams the abscissæ represent the temperature, in the strong curves, that obtained by us, and in the faint, that obtained by Kew; the ordinates in each case being the divergence of the actual readings from these results. Where crosses occur at almost identical temperatures they indicate observations separated by a considerable interval of time, in no case did less than 20 minutes elapse, whilst in others several days.

Three only of our observations are unrecorded on these charts, and in each case, owing to imperfect light, interruptions, &c., these experiments were regarded as doubtful before their results were deduced.

The gradual rise of the zero point is clearly indicated; apparent discrepancies are probably due to the fact that the Kew determinations are less frequent than ours, and as a consequence many of the smaller deviations have escaped notice.

The results show:—

1st. That thermometers whose range does not include 0° and 100° may have certain fixed points determined by this method.

2nd. That an actual calibration of a mercury thermometer can also be readily accomplished.

3rd. That the platinum thermometer, properly constructed, may serve as a standard by which to trace the changes which may take place in mercury thermometers.

4th. That since the readings of the platinum thermometer are independent of the extent of the stem-immersion, it can be conveniently employed for the graduation of thermometers partially immersed, as in ordinary use.

During the past few days, we have calibrated about twenty thermometers by this method, and we believe the results to be satisfactory in all cases.

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## REPORT OF THE COMMITTEE ON ELECTRICAL STANDARDS.

*(Read in Section A, September 9th, 1890).*

### LEGAL OHMS.

THE work of testing resistance coils has been continued at the Cavendish Laboratory. A table of value found for the coils is appended.

| No. of Coil. | | | | | Resistance in Legal Ohms. | Temperature. |
|---|---|---|---|---|---|---|
| Nalder | ... | ... | 1577 | C.L.C. 189 | ·99981 | 16·9 |
| Nalder | ... | ... | 1578 | C.L.C. 190 | 1·00089 | 16·9 |
| Nalder | ... | ... | 1579 | C.L.C. 191 | 1·00041 | 16·9 |
| Edison Swan | | ... | 16 | C.L.C. 192 | ·99846 | 13·9 |
| Elliott | ... | ... | 229 | C.L.C. 193 | 1·00028 | 16·9 |
| Elliott | ... | ... | 230 | C.L.C. 194 | 1·00021 | 16·9 |
| Simmons | ... | ... | | C.L.C. 195 | ·99992 | 16.8 |
| Nalder | ... | ... | 1626 | C.L.C. 196 | 1·00045 | 15·3 |
| Nalder | ... | ... | 1627 | C.L.C. 197 | 1·00056 | 15·3 |
| Nalder | ... | ... | 1628 | C.L.C. 198 | 1·00058 | 14·8 |
| Nalder | ... | ... | 1580 | C.L.C. 199 | 1·00072 | 15·3 |

### B.A. UNIT.

It would be of considerable advantage in the testing if all the coils were made of a uniform size. The original Standards of the Association measure 6¾ inches from the bottom of the case to the underside of the horizontal portion of the copper connecting rods, while the vertical portion of these rods is 8 inches in length. These dimensions should be adopted in all coils sent to be tested; if this be done the baths, &c., made to hold the standards hold the coils equally well, and the additional convenience in testing is very great.

The original Standards of the Association have again been several times compared among themselves.

The results of the comparisons appear to show that while the coils A, B, C, D, E, and Flat have remained constant relative to each other, the three platinum silver coils F G and H have changed.

The change in F was referred to at the end of the Report in 1888, and is now very large. The coil has increased in resistance by about ·0006 B.A. units; G, on the other hand, has fallen by about 0002 B.A. units, and H by about ·0001 unit. The evidence for these various statements is given in an appendix to the Report by the Secretary.

It is perhaps worth remark that in each case the change either took place during the time that the coil was immersed in ice or was found to have happened when the coil was next measured after its removal from the ice.

The legal ohm coils have not varied relative to Flat.

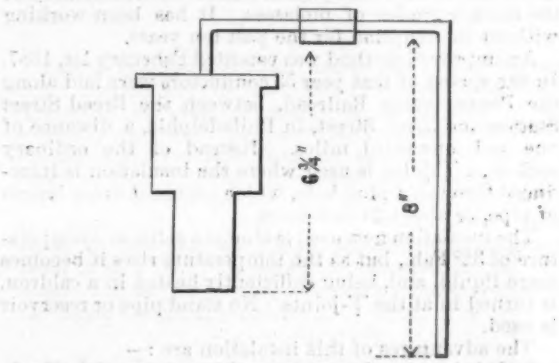
The investigations into the resistance of copper have been continued by Mr. Fitzpatrick. The Committee desire again to thank the gentlemen who have rendered him assistance in various ways.

Mr. Fitzpatrick has examined various specimens of copper supplied him as wire. He has also examined copper prepared for him as pure by Messrs. Sutton, as well as some which he prepared himself electrolytically from carefully purified copper sulphate. These last two specimens lead to practically the same value as that obtained by Matthiessen for the specific resistance of copper—viz., $1767 \times 10^{-9}$ B.A. units at 18°, the specific gravity of these specimens is about 8·90. Two wires supplied to him have, however, a distinctly lower resistance: the value for one being $1731 \times 10^{-9}$ and for the other $1724 \times 10^{-9}$; a difference in the one case of 2 and in the other of 2·4 %. The specific gravity of the first of these wires is 8·940 and of the other 8·946, and Mr. Fitzpatrick assigns the increased conductivity to increased density rather than to greater purity.

Matthiessen gives his results for the resistance of copper at 0°. The observations were, however, made mostly at a temperature of 18° or 20°, and reduced to 0° by the use of a temperature co-efficient. So that the value at 18° found from that at 0° by the same co-efficient will probably represent the result of Matthiessen's work more accurately than the one he gives himself. Various other points of importance are discussed in Mr. Fitzpatrick's appendix. He hopes to be able to give the results for some copper prepared by chemical means by Mr. Skinner and himself. He has also made a number of measurements on silver, but these are not yet complete.

Dr. Muirhead and the Secretary have both been working independently at the construction and measurement of a standard air condenser.

Two such condensers have been made for the Committee by the Cambridge Scientific Instrument Company, on a plan suggested by Dr. Muirhead, and mentioned in the last Report. The capacity of each of these is about ·02 microfarad. Some slight alterations are required to one of these, the other is completely satisfactory. Its capacity has been repeatedly found, and remains constant to at least within 1 in 2,000, which is about the limit of accuracy attained. Its insulation resistance is good, the loss by leakage being about 1 in




1,000 of the total charge per 1 minute. It has been found possible to compare readily with this standard various mica condensers having capacities of 1, ·5, ·1, and ·05 microfarad. The accuracy of these determinations is about 1 in 2,000. A full account of the construction of the condensers, and of the method of making the various tests, is given in an appendix by the Secretary, while Dr. Muirhead has contributed some notes on his own condensers and tests.

Another appendix contains an account of a very careful and interesting comparison between the standard mercury thermometers of the Association and a platinum resistance thermometer constructed by Mr. E. H. Griffiths. The resistance thermometer was graduated by means of Regnault's numbers for the vapour pressure of water at various temperatures between 0 and 100.

The curve of corrections obtained in this way is exactly parallel to that given by the Kew comparisons; there is throughout the range a constant difference of 0°·02 between them. This amount is within the limits of error on the mercury thermometer.

The question of the best value to adopt for the dimensions of a mercury column having a resistance of one ohm has been raised by some members of the Committee during the year. There is no doubt that the column of 106 centimetres adopted by the Paris Conference in 1884 is too short.

After a discussion of the results of the most recent observations, the following resolutions were adopted by the Committee:—

(1) The Committee recommend for adoption as a standard of resistance sufficiently near to the absolute ohm for practical purposes the resistance of a column of mercury 106·3 c.m. in length 1 square mm. in section at a temperature of 0° C.

(2) That for the purpose of issuing practical standards of resistance the number ·9866 be adopted as the ratio of the B.A. unit to the ohm.

Thus the new unit may be obtained from the B.A. unit by increasing it in the ratio ·9866 to unity, or, to put it differently, the specific resistance of mercury in B.A. units is taken as $·9535 \times 10^{-4}$, and the length of a column of mercury which has a resistance of one B.A. unit as 104·97 c.m. The specific resistance of mercury in ohms is $·9407 \times 10^{-4}$.

In conclusion the Committee wish to ask for reappointment to enable them to continue the work of constructing and issuing standard instruments. Of the grant of £50 made at Newcastle only £12 17s. has been drawn. In order to check any further change in the values of the B.A. units, and to render it less necessary to employ the original standards in all the comparisons which are made, it is desirable that the Committee should possess three or four copies of the B.A. unit; while, to enable comparisons to be made between the new air condensers and condensers of capacity compatible with a microfarad, a resistance box going up to several hundred thousand ohms is required.

The Committee are of opinion that they should be in a position to purchase these resistances; they therefore recommend that they be reappointed with a grant of £100, that Professor Carey Foster be the Chairman, and Mr. R. T. Glazebrook Secretary.

## LIQUID INSULATION FOR UNDERGROUND CONDUCTORS.

By DAVID BROOKS.

THE first work on this system for practical purposes was laid for the English Post Office in 1880, along the South Western Railway between Waterloo Station and Clapham Junction.

It consisted in boiling cotton covered conductors in paraffin oil and drawing them into 1¼ inch diameter iron pipe and afterwards filling the pipe with oil. There were 40 conductors of No. 18 B.W. gauge. Reservoirs were placed at elevated positions at Clapham and Waterloo to supply the loss of oil from leakage. The oil used was the ordinary petroleum fluid. The only difficulty experienced was from leakage through the joints of the pipe. This was remedied by the introduction of a heavy rosin oil of the consistency of the thicker grades of molasses. It has been working without interruption for the past ten years.

An improved method was patented February 1st, 1887. In the spring of that year 53 conductors were laid along the Pennsylvania Railroad, between the Broad Street Station and 32nd Street, in Philadelphia, a distance of one and one-third miles. Instead of the ordinary sockets, a ⊤-joint is used where the insulation is introduced through a plug hole, which occurs at every length of pipe, or about 20 feet apart.

The insulation now used is almost a solid, at a temperature of 32° Fah., but as the temperature rises it becomes more liquid, and, being sufficiently heated in a caldron, is turned in at the ⊤-joints. No stand pipe or reservoir is used.

The advantages of this insulation are :—

1. It is heavier than water and is not penetrated by it.
2. Always being liquid it does not crack, or contain small fissures for the admission of dampness.
3. It is not easily punctured by atmospheric electricity or currents of high voltage.
4. The insulation expands and contracts by every change of temperature, and thereby prevents the current centering upon any weak portion and developing a fault, as is often done in other kinds.

Other advantages of the system are :—

1. *Mechanical Strength.*—The wrought iron pipe is proof against penetration or injury by workmen's tools in street repairing.
2. *Cheapness.*—Iron pipe has five times the capacity of lead pipe of equal cost per foot, without making allowance for its greater strength and durability.
3. It is often said of conduits as compared with this system, that there are extra ducts for an increase of conductors when necessary. If the total cost of any conduit, including manholes, is divided by the number of ducts, the cost per foot is ascertained. Each duct of itself costs twice as much as the total cost by the liquid system, using all the conductors that the duct is capable of containing.
4. Conductors can be looped out of the pipe at any desired point to street lamps or for house-to-house purposes, by simply unscrewing a plug and inserting a smaller pipe, very much as gas or water is introduced.

When the cable was laid on the Pennsylvania Railroad, they had use for only 25 conductors, which left 28 idle. Since then, increase of business has brought five more into use. Provision was made for an increase. Extra conductors can be drawn into the pipe when the cable is laid, much cheaper than providing a place for them, as is done in the conduit system.

In the preceding article regarding conduits, the objections made to them are entirely obviated by the use of this system, inasmuch as the insulation is hermetically sealed from the effects of damp air and gases.

The cable laid at Gloucester is now working with a potential of 3,000 volts, alternating between conductors which are in the same pipe. It has 22 terminals exposed to the weather, and the insulation, making allowance for temperature, is as high as when first laid.

## NOTES.

**Electric Lighting in Berlin.**—Some notion may be arrived at of the extension of electric lighting systems in Berlin from the following figures :—

| August of | ... | 1885 | 1886 | 1887 | 1888 | 1889 |
|---|---|---|---|---|---|---|
| Ampères | ... | 1,462 | 5,875 | 7,827 | 13,260 | 22,000 |

**The Electric Light in Libraries.**—At the meeting of the Library Association of the United Kingdom held last week at Reading, Mr. W. H. Greenhough, the librarian at Reading, in a paper on "The Ventilating, Heating and Lighting of Libraries," drew attention to the evil effects of gas used in reading rooms. There is great need of improvement in most reading rooms with which we are acquainted. Too often, they are pleasant places rendered dangerous by the hot, stifling air. A large quantity of light must be supplied, and, consequently, gas brackets are placed in every accessible corner. We imagine that nowhere are the deleterious effects of gas felt more than in reading rooms. As to libraries it is a most important matter for those responsible for books to see that the wear and tear of their treasury is mitigated, and by using the electric light, bindings would be kept in good condition for an infinitely longer period than would be the case under a gaseous *régime*.

**Lighting of Reading Library.**—The Reading Library Committee has entered into a contract with the Electric Light Company specifying that the sum of £80 per annum should be paid for the supply of the current to the eight arc lamps to be used in the library and reading rooms, for providing the necessary carbons, and for keeping the lamps in order. The total illuminating power at the library is to be equal to 4,320 candles. The cost of gas formerly consumed in the library was £79 odd, while the total illuminating power was equal to some 1,360 candles. The result of the experience gained at Reading showed that, excellent though the electric lighting method was, yet, owing to the flickering and occasional failure of a lamp to light from one cause or another, it could by no means be said to be perfect.

**Electric Headlights on Locomotives.**—Electric headlights will be used in future on all passenger trains of the Louisville, New Albany and Chicago Road Railway.

**Electric Lighting in Havana.**—Reports to hand show that electric lighting is progressing rapidly. Some two years ago a local company was formed to work on the Westinghouse system. An apparatus, consisting of two 750 alternate current dynamos, was at once installed at the new central station; but before the wiring had been completed, so numerous were the demands for the supply of light, that the company immediately telegraphed to the United States for an alternating current plant for a capacity of 3,000 incandescent lights. Since this was erected the company have done good business and the demand will soon again exceed the supply. The Westinghouse Company is preparing further plant for shipment.

**Electric Lighting in Madrid.**—The Electricity Supply Company for Spain, acting under a concession from the local authorities, has recently erected a central station in Madrid, and houses at a distance of two miles from the works are being satisfactorily lighted. The cost of the station is £80,000, and the electricity is distributed by underground mains. The station is on the same lines as those proposed for Leeds by the Yorkshire House-to-House Electricity Company, being similar to the one erected by that company's engineers at Kensington.

**Light at the Gold Coast.**—The electric light is being used at the Gold Coast to assist the Apolite Company's quartz crushing operations. The installation comprises 15 arc lamps.

**Continental Lighting.**—The Railway Station and Post Office at Ulm will be lit by electricity after December 1st next. At Florence the municipal authorities are in treaty with the International Electricitäts Gesellschaft of Vienna for the establishment of an electric central station outside the city on the Ganz system for 10,000 lamps.

**Electric Lighting at Tiverton.**—At the last meeting of the Tiverton Town Council, it was resolved to appoint a committee to take into consideration the best means of carrying into operation the powers conferred upon the council by the Tiverton Electric Lighting Order, 1890. It was mentioned by Mr. Grason that the electric light would be cheaper than gas.

**Electric Lighting at Weybridge.**—An installation of 170 lamps has been made at Brooklands, Weybridge, Surrey. The engine-house is situated about a quarter of a mile from the mansion. The plant consists of a new 10 H.P. Marshall's locomotive boiler, fed by a Worthington pump, supplying, at 80 lbs. pressure, an old form of horizontal steam engine made by Hayward and Tyler, hitherto and still used to drive a circular saw. At night the engine is employed to drive a shunt wound dynamo, by Mackie, giving a current of 60 ampères at a tension of 150 volts. The current is conveyed to the house by underground lead-covered cables, protected by glazed pipes with cemented joints. The installation has proved in every way a success.

**Personal.**—Mr. A. J. Howes is about to set out for Cairo, to undertake the erection of an electric installation at the Mena Hotel, Cairo.

**Fire.**—We are desired by Messrs. Cathcart and Peto to state that the recent fire at their Hatton Garden works will in no way interfere with their business.

**Water Power for an Electric Light Station.**—We have, on a former occasion, referred to the projected central station at Innsbruck, in Austria, and we are now in a position to give a detailed account of the work, taking the figures from a lecture by Director Geyer, of Augsburg. The design and construction of this installation is that of Messrs. Ganz & Co., of Buda-Pest. There is a waterfall at Muehlau, near Innsbruck, capable of furnishing a maximum of 600 H.P. The fall is 117 metres, giving a pressure upon the turbines of about 11·5 atmospheres. The water is led through pipes, 350 millimetres in diameter, to a pair of vertical turbines of 160 H.P. each. These turbines run at 250 revolutions per minute, and are coupled, direct, to two alternators, each capable of producing 40 ampères with 2,000 volts. There are two exciters running at 700 revolutions per minute, giving 60 ampères and 110 volts. The present capacity is 2,000 lamps of 16 C.P. each. The high tension current is carried on overhead conductors (eight mm. diameter) to a distance of about four kilometres till it reaches the outskirts of the town of Innsbruck; from there the current is distributed through a concentric main 5·86 kilometres in length. Until recently, the distribution of current has been as follows:—

| | | | | | |
|---|---|---|---|---|---|
| 207 | incandescent lamps, | each 10 | C.P., | taking... | 39 watts. |
| 510 | " | " 16 | " | " | 56 " |
| 79 | " | " 32 | " | " | 112 " |
| 1 | " | " 50 | " | " | 195 " |
| 1 | " | " 100 | " | " | 390 " |
| 3 | arc lamps | ... | ... | ... | each 800 " |
| 1 | electric motor of 5 H.P. | | | | |
| 1 | " " 10 " | | | | |

Total, 51,466 watts.

The minimum consumption was 8,000 watts, and the maximum at any time 40,000 watts. The building of this central station is high up on a hill commanding a beautiful view, and it has been constructed of stones found in neighbouring quarries. For the purpose of transporting the machinery to the spot, special roads had to be cut, involving a good deal of labour. The entire work—buildings and installation—has been carried out in excellent style.

**Electric Fire Accident in Paris.**—Parisians and others who happened to be on the Boulevard des Capucines on Thursday evening, the 18th inst., were considerably startled by the sudden extinction of the electric lights, and the issuing of dense clouds of smoke from an opening in the roadway in front of one of the lamps. It appears that the underground system of the Compagnie Popp had taken fire at the part between the Rue Danon and the Rue des Capucines. This gave rise to some groundless apprehension of an explosion on the part of the public. The damage was repaired in a couple of hours, during which time the neighbourhood was in complete obscurity, to the great inconvenience of traffic.

**Cable Interruption.**—The French Government cable between Soussa and Sfax, on the coast of Tunis, has been broken. This cable was laid in 1882, and, considering the nature of the bottom, and the dangers which cables along this coast are subjected to at the hands of sponge fishers, it may be regarded as having lasted well.

**Lyons Tramway.**—Experiments have been successfully carried out on the Lyons Monplaisir-la-Plaine Tramway in adapting electrical propulsion to the ordinary tramcars. One of these cars was fitted with electric motors worked from 56 accumulator cells. A speed of from 12 to 14 kilometres per hour was maintained during the double journey between Lyons and the station at Monplaisir. The accumulators were made by the firm of Alioth, and are able to supply from 8 to 9 H.P. for eight consecutive hours. The comfort of the passengers was greatly increased by the car being electrically lighted.

**A New Telephonic Experiment.**—An experiment with the telephone is to be made in Birmingham next Sunday. Transmitters will be set up in Christ Church, New Street, so that subscribers to the telephone, if they desire, can hear the service and the sermon at their private residences. The general manager of the company has been encouraged to make the trial by the success which attended a similar scheme initiated by him eight years ago at Bradford. At the end of the choir stalls, on the top of the lectern at the reading desk, and at the pulpit desk, small metal cased transmitters will be placed, and they will be so regulated that sound vibration will be taken up without requiring the voice to be directed immediately upon the plate of the transmitter.

**Electric Welding.**—The wire for covering the tube of the new 10-inch gun, now in course of construction for the United States, is being joined by the electric welding process.

**Westinghouse Strike.**—The strike of the *employés* of the Westinghouse Company at Pittsburg was terminated on September 3rd by the capitulation of the strikers, who requested their old places.

**The Chinese Telegraph Convention.**—In the petition presented by the English merchants resident in China, many complaints are made against the cable companies. According to their statements, they have not derived the advantage which was to be expected from the two separate lines of the Eastern Extension and the Great Northern of Copenhagen, because the two companies, since 1875, have been working in combination, and maintained a rate of 6s. a word between Hong Kong and Europe. They can only communicate with America through Europe. The Convention of 1887 between the Chinese Government and the cable companies is referred to in bitter terms; the Government were, under this agreement, compelled to charge the same rate over their land lines to Europe as the companies. They beg that the Convention may not be ratified by Her Majesty's Government.

**Ship Wiring.**—The New York *Times*, of September 5th, commenting on a threatened fire on board of the *Etruria*, during a then recent passage across the Atlantic, caused by a short circuit in the electric leads, takes the opportunity of comparing the English and American methods of ship wiring, unfavourably to the former system. The article states that all the first-class liners running between England and the United States are wired on the single-wire system, in which the hull of the ship is utilised as the return wire, this plan being the cheapest way yet devised, owing to the large saving in copper, and from the inexpensive manner in which the wires are slung up, as well as from the small number of fusible plugs usually employed. In contradistinction to the danger that is ever present in a ship wired in the English fashion, the American method is so exhaustively perfect in every detail, that it is almost a moral impossibility for any accident, by fire or shock, to occur. The leads are protected first by the insulation, then by a lead covering to prevent corrosion, and, finally, by a wooden casing, from all mechanical injury. Fusible plugs are provided for each lamp. The junction boxes and cut-out boxes used in the American system of marine work are equally complete and much superior to the English construction. The boxes are waterproof and almost hermetically sealed, supplied with stuffing boxes and water-tight covers. Nothing but the cheapness of the English system can account for its criminal employment on the finest steamers in the world. So much from the New York *Times*, whose article reads like an excerpt from some glowing and gushing prospectus, the truth of which, at least in its practical development, may possibly be open to some doubt. In this doubt the gentleman who sent us the article joins, and is amazed at the presumptive tone in which it is couched, and further states, from a five years' experience, he believes that nearly all the wiring on the American side is simply slung up in the roughest manner. However true these statements may be, it is not improbable that the competition in securing contracts for ship lighting in England and Scotland does lead to inferior work and material being used on board ship, and, in the absence of efficient and thorough outside control in the selection of material, and of their proper disposition during the progress of the work, may eventually result in some serious disaster at sea.

**City and Guilds of London Institute.**—Prof. Ayrton's special course for *outside* students will be given every Monday and Wednesday, at Exhibition Road, at 3 p.m., commencing Monday, October 6th. The subject will be "The Construction of Direct and Alternate Current Dynamos and Motors, and the Methods of Testing their Power and Efficiency."

**Obituary.**—M. Gavarret, author of a "Traité d'Electricité," published in 1857, and of a "Traité de Télégraphie Electrique," published in 1849, and also of a treatise upon the electro-physiological researches of Galvani, published in the *Annales de Chimie et Physique*, has just died, aged 81.

**Electric Hair Curler.**—By the aid of this useful and beautiful invention, the hair, beard, or moustache can be curled in any style in one minute. It produces any form desired by ladies wearing their hair in the fashionable "loose and fluffy mode." Thus runs the wrapper of an article which has been submitted to our notice. We are told to hold the curler in the gas a few seconds, very little heat being required, on account of its highly magnetic qualities. Unfortunately our editorial hair, when worn, is neither "loose nor fluffy," and we must leave the testing of the instrument to others.

**The Story of Laying a Cable.**—Mr. Herbert Laws Webb, New York, will contribute to the October number of *Scribner's* an article entitled, "With a Cable Expedition," descriptive of the process of cable laying, and the life on board ship.

**French Telephones.**—M. Selves intends to reorganise the State service entirely. He proposes to suppress five of the eleven intermediary offices and establish one central office in their place. This central office will be occupied with the service of 6,000 of the total 8,800 subscribers, and will be located near to the Hôtel des Postes, at a cost of 800,000 francs, exclusive of building expenses.

**Jamaica Industrial and Manufacturing Exhibition.**—The contract for lighting this exhibition has been secured by Messrs. Nicholson and Jennings, of 7, Westminster Chambers, Victoria Street, S.W., who have tendered in accordance with the specification prepared by Mr. Kenneth Mackenzie, of 15, Great George Street, Westminster, who is acting as consulting engineer to the commissioners. This exhibition will be opened in January next, and will remain so for at least three months; being the first exhibition held in that part of the world, it is naturally creating considerable attention. The contract includes motive power and plant for an equivalent of 70 arc lamps and 650 glow lamps, or equal to an electrical output of 74,000 watts; and, since the buildings which are being erected will be spacious and of an elegant design, the effect, both in the interior of the exhibition as well as the ornamental grounds will be very striking. The contract also includes two electric motors of 20 H.P. each, for running some of the counter-shafting supplying power to exhibitors. The West Indies are at present, certainly as far as regards the enterprise of English electrical contractors, altogether untouched, since the greater part of whatever has been done there up to now has been supplied from the United States; and it is thought that a considerable impetus will be given to trade by the fact of this exhibition being organised by the government of the largest English colony there. We understand that Mr. Mackenzie will be glad to give information and particulars to any electrical firms who might feel inclined to utilise the advantages which this exhibition will offer for opening up a trade in the West Indian islands and Central America.

**The Electric Light on the German Railways.**—In Germany, on the railway lines on the banks of the Rhine, the electric light has been employed for some years with success. The *Voss Gazette* now informs us that the directors of the Prussian railways are about to light, as a trial, a certain number of carriages with incandescent lamps. Five of these lamps will be installed in each carriage. The intensity of the light can be regulated by the passengers as they wish.

**The African Telegraph Service.**—The first telegram direct from the German-African coast arrived last week in Hamburg. It was addressed by Serva Hadji to Captain Baron Von Gravenreuth, and ran as follows:—"Lauterberg from Bagamoyo. Gravenreuth Salaam. Serva Hadji. Two members of the telegraph staff have just left Marseilles for Dar-es-Salaam with a view to organising the telegraph service there."

**Dry Batteries.**—The following directions, with reference to a dry battery manufactured by an American firm, suggests that the name *dry* has been given by an inhabitant of the Emerald Isle. "To fully charge battery remove the cover and pour in slowly through the holes in the top *one gill of pure water*."

**Telephone and the Benwell Murder.**—So great is the interest in this case, that telephone wires have been connected from the Court to a neighbouring hotel. Transmitters are placed near the heads of the counsel, thus enabling the trial to be heard with distinctness. The wires, which almost obstruct the view, called forth a protest from the judge.

**Double-Cylinder Phonograph.**—An improved phonograph has been invented by an American which takes a record on two cylinders simultaneously.

**Electric Cars in Leeds.**—The Thomson-Houston Company has offered to equip a section of line in Leeds with electric cars, and pay a nominal rent of 100 guineas a year. If, on the expiration of two years, the Corporation decides to adopt electricity as the motive power upon the tramways, it will be able to take over the concern from the American company at a valuation. This will be no doubt favourably considered by the Highways Committee.

**The Electro-Harmonic Society.**—The concerts of this season—the fifth—will be six in number, and are announced to take place on the evenings of the following dates:—Friday, October 3rd, 1890, Smoking Concert; Friday, November 7th, 1890, Smoking Concert; Monday, December 8th, 1890, Ladies' Night; Friday, January 30th, 1891, Smoking Concert; Friday, February 27th, 1891, Ladies' Night; Friday, April 10th, 1891, Smoking Concert. At the first of the series Messrs. A. Thompson, W. G. Forington, W. Nicholl and Frederick Upton will perform, whilst the instrumental portion of the programme will be in the hands of Messrs. T. E. Gatehouse and Alfred Izard.

**Wade's Patent Arc Lamp Tablets.**—With the view of utilising the strong light of the arc lamp for advertising purposes, transparent tablets are now manufactured, lettered in various colours, and so made as to fit any type of lamp. Some are constructed of two bent

panels joined at the ends, forming an oval enclosure for the lamp, and others of four panels, forming a square enclosure for the lamp. They do not diminish the light, and are effective both by day and night. They are supplied by the Woodhouse and Rawson United Company, Limited.

**Telephone Induction Coils.**—The article on Telephone Induction Coils, which we give in our present issue, opens up an interesting subject. Those who have experimented largely with different forms and sizes of coils for telephonic purposes can hardly fail to have been struck with the extraordinarily small difference which is found to exist in the working qualities of the different types—long coils, short coils, coils of small diameter, coils of large diameter, coils with large cores, and coils with small cores all seem to give very nearly similar results; even the gauge of wire used in the primary and in the secondary makes surprisingly little difference. The cause of all this has, we believe, never been explained, nor attempted to be explained. Great hopes were entertained that coils on the transformer principle would give remarkably good results, but quite the contrary turned out to be the case, and the reason is now evident if it were not so before.

**Electric Lighting in Chelsea.**—In the report of the surveyor to the parish, we find the following remarks: There are in Chelsea actually using the electric light, about 139 houses supplied as follows, viz.:—

| | | |
|---|---|---|
| Chelsea Electricity Supply Co. .. | ... | 113 houses. |
| Cadogan Electric Light Co. ... | ... | 25 ,, |
| London Electric Supply Corporation ... | | 1 ,, |
| | | 139 |

It should be borne in mind that the desire for electric light in Chelsea is not, as in most parishes, an outcome of the electric lighting mania of 1882, but dates from some four years prior to that period, and that what at first sight looks like slow progress, is really the natural growth of an important industry which, in each stage of its advancement, bears marks of the careful attention bestowed upon it by the Chelsea vestry.

## NEW COMPANIES REGISTREED.

**Electrical Inventions Company, Limited.**—Capital, £35,000 in £1 shares. Objects: To acquire, work, develop and deal with patents of electrical inventions and improvements, and of electrical instruments and apparatus of every description, whether patented or not. Signatories (with 1 share each): W. Dare, 15, Stansfield Road, Stockwell; S. B. Witherby, 5, Holly Villas, Highgate; A. Good and A. W. Good, 57, Moorgate Street; R. Radermacher, 16, Golborne Road, W.; Bruce Kedge, 29, Morrison Road, S.W.; C. Jellicoe, 74, Godolphin Road, Shepherd's Bush. The signatories are to appoint the first directors; qualification for subsequent directors, £100 in shares; the company in general meeting will appoint remuneration. Registered 18th inst. by A. W. Rixon, 10, Austin Friars.

**J. E. H. Gordon and Company, Limited.**—Capital, £50,000 in £10 shares. Objects: To acquire as a going concern the business of electrical engineer carried on by J. E. H. Gordon, M.Inst.C.E., and to construct, manufacture, supply, and maintain electric light machinery and apparatus. Signatories (with 1 share each): *J. E. H. Gordon and Mrs. Gordon, 1, Queen's Gate Gardens; *W. J. Rivington and Mrs. Rivington, 21, Gledhow Gardens, South Kensington; Mrs. E. C. Gordon and Miss E. C. Gordon, Hornlow Cottage, Campden Hill, W.; Hy. Sinclair, 11, Pall Mall. The signatories denoted by an asterisk are the first directors; qualification, 200 shares. Registered 19th inst. by Messrs. Mann and Taylor, 109, New Oxford Street.

**Combination Telephone and Electrical Engineering Company, Limited.**—Capital, £20,000, in £1 shares. Objects: To acquire and work the letters patent, Nos. 5,008 and 7,553, both of 1890, relating to telephones, and to take over as a going concern the business of Charles James Grist, carried on at 43, Sydney Street, Oxford Road, Manchester. To carry on the business of a telephone, telegraph and electric light, heat and power supply company. Signatories (with one share each): A. Lewis, 204, Elgin Avenue, W.; T. J. Cook, 4, Bovill Road, Forest Hill; H. C. Fowler, St. Paul's Road, Tottenham; H. T. Raw, 140, Birchanger Road, Woodside, S.E.; S. N. Smith, 68, Holmes Road, Kentish Town; T. E. Halford, 33, Priory Road, Bedford Park; C. Howard, 59, Lennox Road, Walthamstow. Messrs. C. J. Grist and E. Frank Furtado are appointed managing directors, each at a salary of £300 per annum. The ordinary directors will be entitled to £75 per annum each, with £45 additional to the chairman. Qualification, 50 shares. Registered, 19th inst., by Ernest Salaman, 65 and 66, Chancery Lane. Registered office, 35, New Broad Street.

**J. H. Holden and Company, Limited.**—Capital, £1,000, in £1 shares. Objects: To carry on business as cotton, wool, flax, hemp, jute and yarn merchants. To generate, use, let, or supply electric, gas, steam, or other power. Signatories (with one share each): J. H. Holden, Tonge; P. Crook, Bolton; W. Schmid, Bolton; F. T. Hilton, Bolton; Miss A. Nuttall, Bolton; P. Kirkham, Preston; Mrs. M. Holden, Bolton; all in

Lancashire. Registered, 19th inst., without special articles, by R. Jordan, 120, Chancery Lane. Office, Bradshawgate, Bolton, Lancaster.

## OFFICIAL RETURNS OF ELECTRICAL COMPANIES.

**British Electric Propulsion and Traction Company, Limited.**—The annual return of this company, made up to the 18th inst., was filed on the same day. The nominal capital is £5,000, in £1 shares. 3,241 shares have been issued, 3,184 being considered fully paid. Upon 57 shares the full amount has been called and paid.

**Woodhouse and Rawson United, Limited.** — An agreement of 3rd inst. (filed 15th inst.) is supplemental to an agreement of 15th July entered into with Woodhouse and Rawson Electric Manufacturing Company, Limited (called the vendor company). The sale and purchase of the property referred to in the principal agreement has not yet been completed, for divers reasons, principally legal questions between the vendor company and other parties as to certain important assets. Until settlement thereof, it is deemed desirable that no steps should be taken for the liquidation of the company, and it is agreed to modify the terms of the principal agreement. It is therefore agreed that the purchase money payable shall be apportioned as follows :—

| | |
|---|---|
| The plant, other than incandescent lamp plant ... | £5,250 |
| The stock, other than stock of incandescent lamps | 11,750 |
| Patents and licences ... ... ... ... ... | 11,000 |
| Goodwill ... ... ... ... ... ... ... | 3,500 |
| Stock of incandescent lamps, and incandescent lamp plant ... ... ... ... ... ... | 500 |
| | £32,000 |

The sum of £23,000 is payable in ordinary shares and in fully paid shares.

An agreement of 3rd September (registered 15th inst.) with the Woodhouse and Rawson Electrical Supply Company of Great Britain, Limited, is also supplemental to an agreement of 15th July. For similar reasons the purchase consideration is modified until the settlement of the question involved, to £15,000, of which £12,500 is payable in fully paid shares.

## CITY NOTES, REPORTS, MEETINGS, &c.

### The Direct Spanish Telegraph Company, Limited.

THE report of the directors for the half-year ended 30th June, 1890, to be presented at the general meeting of shareholders, to be held on Tuesday, September 30th, 1890, states that the accounts show, after providing for debenture interest, a balance to the credit of profit and loss of £7,199 17s. 2d. The traffic receipts have again been satisfactory, and show an increase of £2,057 1s. 8d. as compared with the corresponding half-year of 1889. The working expenses are £391 0s. 8d. in excess of those for the corresponding period of last year. The company's cables, and the land-lines in connection with them, have continued in good working order throughout the half-year. The company was represented at the International Telegraph Conference held at Paris in May last, and had, as well as other telegraph companies and administrations, to submit to reductions of tariff which will affect the company's revenue to some extent. These reductions do not come into force until the 1st July, 1891.

An extraordinary general meeting will take place immediately after the ordinary general meeting, in accordance with the following resolution which was unanimously adopted by the shareholders at the last ordinary general meeting.

"That in the opinion of this meeting the directors' remuneration should be now increased beyond the sum of £400 per annum, and that in view of their declared intention not to avail themselves of their rights under the 71st of the company's articles of association as it now stands, the directors be, and are hereby requested, to give notice of a special resolution being brought forward at the next half-yearly meeting for altering article 71, so as to increase their remuneration to £600, or otherwise, as may from time to time be voted in general meeting."

Of the balance of profit and loss, £2,500 have been put to the reserve fund, which now amounts to £20,258 6s. 6d., leaving a balance of £4,699 17s. 2d. Out of this amount the directors recommend the payment of the dividend at the rate of 10 per cent. per annum on the preference shares, and a dividend at the rate of 6 per cent. per annum (free of income tax) on the ordinary shares. This will admit of a sum of £1,685 12s. 9d. being carried to the "contingencies account," which the directors consider it indispensable to maintain, in view of fluctuations of traffic, &c., the reserve fund applying solely to the renewal of the cables.

The dividend warrants will be issued on the 1st October, 1890.

### General Electric Power and Traction Company, Limited.

THE statutory meeting of this company was held at Winchester House, on Tuesday, Viscount Bury presiding.

The Chairman said his task was a purely formal one, the meeting being held, in pursuance of statute, for the purpose of giving the shareholders an opportunity of satisfying themselves, by personal communication with the board, at a short period after commencement of operations, that all the requirements of the various Acts have been complied with, and that everything is in regular and due order. He was happy to say that the affairs of the company were in complete order. No accounts had been issued, because it would be entirely premature to talk about what had been done or what was going to be done in the immediate future. A time would shortly arrive when the directors would have something to say upon those subjects. All he could tell them was that the company, which began as a going concern, was going on in a satisfactory manner. The directors had been constantly and energetically occupied with the various details of the factory, the mining branch, and the launches. The company's electrical cars were running in a satisfactory manner. The electrical works were under the management of Mr. A. T. Snell, who was well known as a most efficient and successful engineer, and who had occupied a high position under Mr. Immisch, at the "Immisch" works. They were very satisfactorily developing the mining plant, and had received very considerable orders in that department. Very satisfactory enquiries had been received from the various departments of electric traction, especially those devoted to tramways. In fact, the company had a future before it which, as he was not addicted to strong language, he would not call brilliant, but which he would call satisfactory, to his colleagues and himself.

A Shareholder would like to know to what extent shares had been taken?

The Chairman thought it was not a strictly regular question; it was certainly no part of the business of the present meeting. But, while anxious to keep within the usual routine, he saw no objection to saying that, with the exception of £8,000, the whole of the shares, ordinary and preference, had been allotted; and the whole proceeds of the preference shares would be devoted to the working of the company.

The proceedings then terminated.

**Elmore's Wire Manufacturing Company, Limited.**—The Stock Exchange has appointed to-day a special settling day for Elmore's Wire Manufacturing Company, Limited, shares Nos. 1 to 67,358, and has ordered the undermentioned securities to be quoted:—Preference shares, Nos. 1 to 50,000; Elmore's Patent Copper, vendors' shares, Nos. 1 to 23,300; Elmore's Wire Manufacturing Company, Limited, shares Nos. 1 to 67,358.

**Elmore's Copper Companies.**—The first batch of letters of allotment in Elmore's French Patent Copper Depositing Company, Limited, has been posted. "We," says a financial paper, "are informed that the issue has been subscribed nearly four times over, the actual number of shares applied for being 253,951." The shares are quoted 1¼ to 1¾ prem. An Austrian Elmore's Copper Company is to be brought out in a few days.

**Stock Exchange Settlements.**—Application has been made to the Stock Exchange to appoint a settling day, and to grant a quotation to the International Okonite Company, Limited, preference shares, Nos. 5,667 to 17,000; ordinary shares, Nos. 22,667 to 34,000; and £517,000 6 per cent. debentures. *Woodhouse and Rawson United, Limited.*—Ordinary shares Nos. 1 to 31,416, and preference shares Nos. 40,001 to 54,285.

**Globe Telegraph and Trust Company, Limited.**—The directors have declared an interim dividend of 1s. 9d. per share, payable on the 18th proximo.

**Eastern Extension, Australasia, and China Telegraph Company, Limited.**—Interim dividend for June quarter of 2s. 6d. per share, payable on the 15th prox., has been declared by the directors.

### TRAFFIC RECEIPTS.

The Brazilian Submarine Telegraph Company, Limited. The traffic receipts for the week ending September 19th, were £4,640.

The Western and Brazilian Telegraph Company, Limited. The receipts for the week ending September 19th, after deducting the fifth of the gross receipts payable to the London Platino-Brazilian Telegraph Company, Limited, were £3,627.

## SHARE LIST OF ELECTRICAL COMPANIES.

| Present Amount Issued. | Name. | Stock or Share. | Closing Quotation. (September 18). | Closing Quotation. (September 25.) | Business done during week ending September 25, 1890. | |
|---|---|---|---|---|---|---|
| £ | | | | | Highest. | Lowest. |
| 250,000 | African Direct Telegraph, Ltd., 4 p. c. Deb. Regd. and to Bearer | 100 | 98 —101 | 98 —101 | 99⅛ | ... |
| 1,549,160 | Anglo-American Telegraph, Limited ... ... ... .. | Stock | 51½— 52½ | 51 — 52 | 51⅞ | ... |
| 2,725,420 | Do. do. 6 p. c. Preferred ... ... ... ... .. | Stock | 88 — 89 | 87½— 88½ | 88½ | 88 |
| 2,725,420 | Do. do. Deferred ... ... ... ... ... | Stock | 15½— 15¾ | 14¾— 15½ | 15⅝ | ... |
| 130,000 | Brazilian Submarine Telegraph, Limited ... ... ... ... | 10 | 11¾— 12¼ | 11¾— 12¼ | 12 | 11⅞ |
| 99,000 | Do. do. 5 p. c. Bonds... ... ... ... ... | 100 | 100 —102 | 100 —102 | 102 | ... |
| 75,000 | Do. do. 5 p. c. 2nd Series, repayable June, 1906 | 100 | 103 —107 | 103 —107 | | |
| 63,416 | Brush Electric Engineering Ordinary, Nos. 1 to 63,416... .. | 3 | 1½— 2 | 1½— 2 | | |
| 63,416 | Do. do. Preference, Nos. 1 to 63,416 ... | 2 | 1⅝— 1¾ xd | 1⅝— 1¾ | | |
| $7,216,000 | Commercial Cable, Capital Stock ... ... ... .. ... | $100 | 103 —105 | 103 —105 | 105 | 103½ |
| 224,850 | Consolidated Telephone Construction and Maintenance, Ltd. ... | 14/- | 9/16— 11/16 | 9/16— 11/16 | | |
| 20,000 | Crompton & Co., Limited, 7 p. c. Pref. Shares, Nos. 1 to 20,000 | Stock | 5½— 5¾ | 5¼— 5½ | | |
| 16,000 | Cuba Telegraph, Limited ... ... ... ... ... ... | 10 | 12½— 12¾ | 12 — 12½ | | |
| 6,000 | Do. do. 10 p. c. Preference ... ... ... | 10 | 17 — 18 | 17 — 18 | | |
| 12,931 | Direct Spanish Telegraph, Limited ... (£4 only paid) | 5 | 4 — 4½ | 4 — 4½ | 4 15/16 | ... |
| 6,000 | Do. do. 10 p. c. Preference ... ... ... | 5 | 9 — 10 | 9 — 10 | 9⅜ | 9 7/16 |
| 60,710 | Direct United States Cable, Limited, 1877 ... ... ... | 20 | 10½— 10¾ | 10¾— 10⅝ | 10⅝ | ... |
| 400,000 | Eastern Telegraph, Limited, Nos. 1 to 400,000 ... ... ... | 10 | 14 — 14¼ | 14 — 14¼ | 14¼ | 14 |
| 70,000 | Do. 6 p. c. Preference ... ... ... ... | 10 | 15 — 15½ | 15 — 15½ | 15¼ | ... |
| 200,000 | Do. 5 p. c. Debs. (1879 issue), repay. Aug., 1899 | 100 | 106 —109 | 106 —109 | | |
| 1,200,000 | Do. 4 p. c. Mortgage Debenture Stock ... ... | Stock | 104 —107 | 104 —107 | 105⅜ | ... |
| 250,000 | Eastern Extension, Australasia and China Telegraph, Limited | 10 | 14½— 14⅝ | 14½— 14⅝ | 14 5/16 | 14½ |
| 320,000 | Do. 6 p. c. Debentures, repay. February, 1891 ... ... | 100 | 100 —102 | 100 —102 | | |
| 446,100 | Do. 5 p. c. (Aus. Gov. Sub.), Deb., 1900, red. ann. drgs. ... | 100 | 103 —106 | 103 —106 | 103 | ... |
| 12,500 | Do. 5 p. c. Debentures, 1890, redeem. ann. drawings ... | 100 | 103 —106 | 103 —106 | | |
| 367,900 | Eastern and South African Tel., Ltd., 5 p. c. Mort. Deb., 1900... | 100 | 102 —105 | 102 —105 | | |
| 45,000 | Electric Construction, Limited, Nos. 101 to 45,100 ... ... | 10 | 7⅞—8¼ | 7⅞— 8¼ | | |
| 19,900 | *Electricity Supply Co. of Spain, Nos. 101 to 20,000 ... | 5 | 4¾— 5¼ | 4¾— 5¼ | | |
| 46,700 | Elmore's Patent Copper Depositing, Ltd., Nos. 23,001 to 70,000 | 2 | 6¾— 7¼ | 6 — 6½ | 7 | 5⅞ |
| 67,385 | Elmore's Wire Manufacturing, Limited, Nos. 1 to 67,385 issued at 1 pm. all paid (£1½ paid) | 2 | ... — ... | ⅛— ¼ | | |
| 19,700 | Fowler-Waring Cables, Nos. 301 to 20,000 ...(£3 only paid) | 5 | 2 — 2½ | 2½— 3 | | |
| 180,227 | Globe Telegraph and Trust, Limited ... ... ... | 10 | 8¾— 9¼ | 8¾— 9¼ | 9 1/16 | 8 15/16 |
| 180,042 | Do. do. 6 p. c. Preference ... ... ... | 10 | 14¾— 15 | 14¾— 15 | | |
| 150,000 | Great Northern Tel. Company of Copenhagen ... ... ... | 10 | 15¾— 16¼ | 15¾— 16¼ | 15 13/16 | 15¾ |
| 40,000 | Do. do. 5 p. c. Debs. (issue of 1881) ... | 100 | 100 —103 | 100 —103 | | |
| 250,000 | Do. do. do. (issue of 1883) ... | 100 | 104 —107 | 104 —107 | 104 | ... |
| 9,334 | Greenwood and Batley, Ltd., Ordinary, Nos. 4,667 to 14,000 ... | 10 | 11½— 12½ | 11½— 12½ | | |
| 5,334 | Do. 7 p. c. Cumulative Preference, Nos. 2,667 to 8,000 | 10 | 11½— 12½ | 11½— 12½ | | |
| 41,600 | India-Rubber, Gutta-Percha and Telegraph Works, Limited ... | 10 | 18½— 19½ | 18 — 19 | 18⅝ | ... |
| 200,000 | Do. do. 4½ p. c. Deb., 1896... ... ... | 100 | 102 —104 | 102 —104 | | |
| 17,000 | Indo-European Telegraph, Limited... ... ... ... .. | 25 | 36 — 38 | 36 — 38 | 37 | 36½ |
| 38,348 | London Platino-Brazilian Telegraph, Limited ... ... ... | 10 | 6½— 7½ | 6½— 7½ | | |
| 100,000 | Do. do. do. 6 p. c. Debentures ... | 100 | 105 —108 | 105 —108 | | |
| 49,900 | *Metropolitan Electric Supply, Limited, Nos. 6,101 to 50,000 ... | 10 | 4 — 4½ | 4 — 4½ | | |
| 436,700 | National Telephone, Limited, Nos. 1 to 436,700 ... ... ... | 5 | 4⅜— 4⅝ | 4⅜— 4⅝ | 4 11/16 | 4 9/16 |
| 15,000 | Do. 6 p. c. Cum. 1st Preference ... ... ... | 10 | 12 — 12½ | 12 — 12½ | 12 7/16 | ... |
| 15,000 | Do. 6 p. c. Cum. 2nd Preference (£8 only paid) | 10 | 10 — 10½ | 10 — 10½ | | |
| 220,000 | Oriental Telephone, Ltd., Nos. 80,001 to 300,000 (11/- only paid) | 1 | ⅛— ⅜ | ⅛— ⅜ | | |
| 9,000 | Reuter's, Limited ... ... ... ... .. ... ... | 8 | 8 — 8½ | 8 — 8½ | | |
| 209,750 | South of England Telephone, Ltd., Ordinary, Nos. 1 to 2,000, 2,501 to 3,500, 93,251 to 300,000 | 1 | ⅛— ⅜ | ⅛— ... | | |
| 20,000 | Do. 6 p. c. Cum. Pref., Nos. 1 to 20,000 (£3¼ only paid) | 5 | 2½— 3 | 2½— 3 | | |
| 3,381 | Submarine Cables Trust ... ... ... ... ... ... | Cert. | 113 —117 | 113 —117 | | |
| 78,949 | Swan United Electric Light, Limited ... (£3¼ only paid) | 5 | 5½— 5¾ | 5½— 5¾ | 5 11/16 | 5½ |
| 37,350 | Telegraph Construction and Maintenance, Limited ... ... | 12 | 42 — 44 | 43 — 45 | 44⅛ | 43½ |
| 150,000 | Do. do. do. 5 p. c. Bonds, red. 1894 | 100 | 100 —102 | 100 —102 | | |
| 55,000 | United River Plate Telephone, Limited ... ... ... ... | 5 | 3½— 4 | 3¼— 4 | 3¼ | ... |
| 146,000 | Do. do. 5 p. c. Debenture Stock... ... | Stock | 90 — 94 | 90 — 94 | | |
| 100,000 | Do. do. 7 p. c. Debs., Nos. 1 to 1,000 ... | 100 | ... ... | ... ... | | |
| 15,609 | West African Telegraph, Limited, Nos. 7,501 to 23,109 ... ... | 10 | 9 — 10 | 9 — 10 | | |
| 300,000 | Do. do. do. 5 p. c. Debentures ... ... | 100 | 99 —102 | 99 —102 | 100 | 99¼ |
| 30,000 | West Coast of America Telegraph, Limited ... ... ... | 10 | 4½— 5 | 4½— 5 | | |
| 150,000 | Do. do. do. 8 p. c. Debs, repay. 1902 ... | 100 | 101 —106 | 103 —108 | 106 | 105 |
| 64,572 | Western and Brazilian Telegraph, Limited ... ... ... | 15 | 11 — 11½ | 11 — 11⅛ | 11⅛ | 11⅛ |
| 26,986 | Do. do. do. 5 p. c. Cum. Preferred ... ... | 7½ | 6¾— 7¼ | 6¾— 7 | 7 | 6 15/16 |
| 26,986 | Do. do. do. 5 p. c. Deferred ... ... ... | 7½ | 4½— 5 | 4¾— 5¼ | 5 | 4⅝ |
| 200,000 | Do. do. do. 6 p. c. Debentures "A," 1910... | 100 | 103 —106 | 103 —106 | | |
| 250,000 | Do. 6 p. c. Mort. Debs., series "B" of '80, red. Feb., 1910 | 100 | 101 —104 | 101 —104 | | |
| 88,321 | West India and Panama Telegraph, Limited ... ... ... | 10 | 3⅜— 3⅝ | 3¼— 3¼ | 3¼ | 3¼ |
| 34,563 | Do. do. do. 6 p. c. 1st Preference ... | 10 | 11½— 12 | 11¼— 12 | | |
| 4,669 | Do. do. do, 6 p. c. 2nd Preference ... | 10 | 13½— 14 | 14 — 15 | | |
| 1,336,000 | Western Union of U.S. Tel., 7 p. c. 1st Mort (Building) Bonds | $1,000 | 122 —127 | 122 —127 | | |
| 179,300 | Do. do. 6 p. c. Sterling Bonds ... ... ... | 100 | 97 —99 | 99 —103 | | |
| 42,853 | *Westmstr. Elec. Sup. Corp., Ord., Nos. 101 to 42,953 (£2 only paid) | 5 | 1¼ — 1⅝ | 1¼— 1⅝ | 1⅜ | ... |

* Subject to Founders Shares.

### LATEST PROCURABLE QUOTATIONS OF SECURITIES NOT OFFICIALLY QUOTED.

Blackpool Electric Tramway Company, Limited, £10 (£6¼ paid), 7¼—7⅜.—Elmore Copper Depositing Priorities, 7 —7¼.—Elmore's French Patent Copper Depositing shares of £2 (issued at 10s. premium, 15s. paid), 2¼—2⅜.—House-to-House Company (£5 paid), 5 —5¼.—International Okonite, Ordinary of £10 (£7 paid), 6⅞—7¼.—London Electric Supply Corporation, Ordinary (£5 paid) 2¼—3.—Manchester Edison and Swan Company, £9 (£1 paid) 11/- —13/-.

BANK RATE OF DISCOUNT.—5 per cent. (25th September 1890).

# THE ELECTRO-MAGNET.*

By Prof. SILVANUS P. THOMPSON, D.Sc., B A., M.I.E.E.

(*Continued from page* 332.)

In the next number of "Silliman's Journal" (April, 1831), Prof. Henry gave "an account of a large electro-magnet, made for the laboratory of Yale College." The core of the armature weighed 59½ lbs., it was forged under Henry's own direction, and wound by Dr. Ten Eyck. This magnet, wound with 26 strands of copper bell wire of total length of 728 feet, and excited by two cells which exposed nearly 4½ square feet of surface, readily supported on its armature, which weighed 23 lbs., a load of 2,063 lbs.

Writing in 1867 of his earlier experiments, Henry speaks † thus of his ideas respecting the use of additional coils on the magnet and the increase of battery power:—

"To test these principles on a larger scale, the experimental magnet was constructed, which is shown in fig. 6. In this a

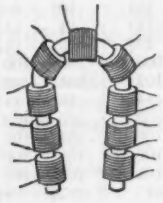


FIG. 6.—HENRY'S EXPERIMENTAL ELECTRO-MAGNET.

number of compound helices was placed on the same bar, their ends left projecting, and so numbered that they could all be united into one long helix, or variously combined in sets of lesser length.

"From a series of experiments with this and other magnets, it was proved that in order to produce the greatest amount of magnetism from a battery of a single cup a number of helices is required; but when a compound battery is used, then one long wire must be employed, making many turns around the iron, the length of wire, and consequently the number of turns, being commensurate with the projectile power of the battery.

"In describing the results of my experiments, the terms 'intensity' and 'quantity' magnets were introduced to avoid circumlocution, and were intended to be used merely in a technical sense. By the intensity magnet I designated a piece of soft iron, so surrounded with wire that its magnetic power could be called into operation by an intensity battery; and by a quantity magnet, a piece of iron so surrounded by a number of separate coils, that its magnetism could be fully developed by a quantity battery.

"I was the first to point out this connection of the two kinds of the battery with the two forms of the magnet, in my paper, in 'Silliman's Journal,' January, 1831, and clearly to state that when magnetism was to be developed by means of a compound battery, one long coil must be employed, and when the maximum effect was to be produced by a single battery, a number of single strands should be used. . . . Neither the electro-magnet of Sturgeon nor any electro-magnet ever made previous to my investigations was applicable to transmitting power to a distance. . . . . The electro-magnet made by Sturgeon, and copied by Dana, of New York, was an imperfect quantity magnet, the feeble power of which was developed by a single battery."

Finally, Henry ‡ sums up his own position as follows:—

"1. Previous to my investigations, the means of developing magnetism in soft iron were imperfectly understood, and the electro-magnet which then existed was inapplicable to transmissions of power to a distance.

"2. I was the first to prove by actual experiment that in order to develop magnetic power at a distance, a galvanic battery of 'intensity' must be employed to project the current through the long conductor, and that a magnet surrounded by many turns of one long wire must be used to receive this current.

"3. I was the first to actually magnetise a piece of iron at a distance, and to call attention to the fact of the applicability of my experiments to the telegraph.

"4. I was the first to actually sound a bell at a distance by means of the electro-magnet.

"5. The principles I have developed were applied by Dr. Gale to render Morse's machine effective at a distance."

Though Henry's researches were published in 1831, they were for some years almost unknown in Europe. Until April, 1837, when Henry himself visited Wheatstone at his laboratory at King's College, the latter did not know how to construct an electro-magnet that could be worked through a long wire circuit. Cooke, who became the coadjutor of Wheatstone, had originally come to him to consult him,* in February, 1837, about his telegraph and alarum, the electro-magnets of which, though they worked well on short circuits, refused to work when placed in circuit with even a single mile of wire. Wheatstone's own account † of the matter is extremely explicit:—"Relying on my former experience, I at once told Mr. Cooke that his plan would not and could not act as a telegraph, because sufficient attractive power could not be imparted to an electro-magnet interposed in a long circuit; and to convince him of the truth of this assertion, I invited him to King's College to see the repetition of the experiments on which my conclusion was founded. He came, and after seeing a variety of voltaic magnets, which, even with powerful batteries, exhibited only slight adhesive attraction, he expressed his disappointment."

After Henry's visit to Wheatstone, the latter altered his tone. He had been using, *faute de mieux*, relay circuits to work the electro-magnets of his alarum in a short circuit with a local battery. "These short circuits," he writes, "have lost nearly all their importance, and are scarcely worth contending about since *my discovery*" (the italics are our own) "that electro-magnets may be so constructed as to produce the required effects by means of the direct current, even in very long circuits." ‡

We pass on to the researches of the distinguished physicist of Manchester, whose decease we have lately had to deplore, Mr. J. P. Joule, who, fired by the work of Sturgeon, made most valuable contributions to the subject. Most of these were published either in Sturgeon's "Annals of Electricity," or in the "Proceedings of the Literary and Philosophical Society of Manchester," but their most accessible form is the republished volume issued five years ago by the Physical Society of London.

In his earliest investigations he was endeavouring to work out the details of an electric motor. The following is an extract from his own account ("Reprint of Scientific Papers," p. 7.):—

"In the further prosecution of my enquiries, I took six pieces of round bar iron of different diameters and lengths, also a hollow cylinder, $\frac{1}{13}$th of an inch thick in the metal. These were bent in the ∪-form, so that the shortest distance between the poles of each was half an inch; each was then wound with 10 feet of covered copper wire, $\frac{1}{10}$th of an inch in diameter. Their attractive powers under like currents for a straight steel magnet, 1½ inch long, suspended horizontally to the beam of a balance, were, at the distance of half an inch, as follows:—

| | No 1. Hollow. | No.2. Solid. | No.3. Solid. | No. 4. Solid. | No.5. Solid. | No.6. Solid. | No. 7. Solid. |
|---|---|---|---|---|---|---|---|
| Length round the bend in inches.. ... ... | 6 | 5½ | 2⅜ | 5½ | 2½ | 5½ | 2½ |
| Diameter in inches ... | ½ | ½ | ½ | ⅜ | ⅜ | ¼ | ¼ |
| Attractionfor steel magnet, in grains... ... | 7·5 | 6 3 | 5·1 | 5·0 | 4·1 | 4 8 | 3·6 |
| Weight lifted, in ounces | 36 | 52 | 92 | 36 | · 52 | 20 | 28 |

"A steel magnet gave an attractive power of 23 grains, while its lifting power was not greater than 60 ounces.

"The above results will not appear surprising if we consider, first, the resistance which iron presents to the induction of magnetism, and, second, how very much the induction is exalted by the completion of the magnetic circuit.

"Nothing can be more striking than the difference between the ratios of lifting to attractive power at a distance in the different magnets. Whilst the steel magnet attracts with a force of 23 grains and lifts 60 ounces, the electro-magnet No. 3 attracts with a force of only 5·1 grains, but lifts as much as 92 ounces.

"To make a good electro-magnet for lifting purposes:—1. Its iron, if of considerable bulk, should be compound, of good quality, and well annealed. 2. The bulk of the iron should bear a much greater ratio to its length than is generally the case. 3. The poles should be ground quite true, and fit flatly and accurately to the armature. 4. The armature should be equal in thickness to the iron of the magnet.

"In studying what form of electro-magnet is best for attraction from a distance, two things must be considered, viz., the length of the iron, and its sectional area.

"Now I have always found it disadvantageous to increase the length beyond what is needful for the winding of the covered wire."

These results were announced in March, 1839. In May of the same year Joule propounded a law of the mutual attraction of two electro-magnets as follows:—"The attractive force of two electro-magnets for one another is directly proportional to the square of the electric force to which the iron is exposed; or if E denote the electric current, w the length of wire, and M the magnetic attraction, $M = E^2 w^2$." The discrepancies which he himself observed he rightly attributed to the iron becoming saturated magnetically. In March, 1840, he extended this same law to the lifting power of the horseshoe electro-magnet.

In August, 1840, he wrote to the "Annals of Electricity" on electro-magnetic forces, dealing chiefly with some special electro-magnets for traction. One of these possessed the form shown in

* Cantor Lecture. Delivered before the Society of Arts, January 20th, 1890.

† Statement in Relation to the History of the Electro-Magnetic Telegraph: from the Smithsonian Annual Report for 1857, p. 99.

‡ "Scientific Writings of Joseph Henry," vol. ii., p. 435,

* See Mr. Latimer Clark's account of Cooke in vol. viii. of "Journal of Society of Telegraph Engineers, p. 3,741, 1880.

† W. F. Cooke, "The Electric Telegraph: was it invented by Prof. Wheatstone?" 1856-7, pt. ii., p. 87.

‡ *Ib.*, p. 95.

Fig. 7. Both the magnet and the iron keeper were furnished with eye-holes for the purpose of suspension and measurement of the force requisite to detach the keeper. Joule thus writes about the experiments* :—

"I proceed now to describe my electro-magnets, which I constructed of very different sizes, in order to develop any curious circumstance which might present itself. A piece of cylindrical wrought iron, eight inches long, had a hole one inch in diameter, bored the whole length of its axis; one side was planed until the hole was exposed sufficiently to separate the thus formed poles one-third of an inch. Another piece of iron, also eight inches long, was then planed, and being secured with its face in contact with the other planed surface, the whole was turned into a cylinder eight inches long, three and three-quarter inches in exterior, and one inch interior diameter. The larger piece was then covered with calico and wound with four copper wires covered with silk, each 23 feet long, and $\frac{1}{11}$th of an inch in diameter—a quantity just sufficient to hide the exterior surface, and to fill the interior opened hole." . . . . "The above is designated No. 1, and the rest are numbered in the order of their description.

"I made No. 2 of a bar of half-inch round iron 2·7 inches long. It was bent into an almost semi-circular shape, and then covered with seven feet of insulated copper wire $\frac{1}{20}$th of an inch thick. The poles are half an inch asunder, and the wire completely fills the space between them.

"A third electro-magnet was made of a piece of iron 0·7 inch long, 0·37 inch broad, and 0·15 inch thick. Its edges were reduced to such an extent that the transverse section was elliptical. It was bent into a semi-circular shape, and wound with 19 inches of silked copper wire, $\frac{1}{10}$th of an inch in diameter.

"To procure a still more extensive variety, I constructed what might, from its extreme minuteness, be termed an *elementary electro-magnet*. It is the smallest, I believe, ever made, consisting of a bit of iron wire $\frac{1}{4}$ of an inch long, and $\frac{1}{16}$th of an inch in diameter. It was bent into the shape of a semi-circle, and was wound with three turns of *uninsulated* copper wire $\frac{1}{10}$th of an inch in thickness."

With these magnets experiments were made with various strengths of currents, the tractive forces being measured by an arrangement of levers. The results, briefly, are as follows:—Electro-magnet No. 1, the iron of which weighed 15 lbs., required a weight of 2,090 lbs. to detach the keeper. No. 2, the iron of which weighed 1,057 grains, required 49 lbs. to detach its armature. No. 3, the iron of which weighed 65·3 grains, supported a load of 12 lbs., or 1,286 times its own weight. No. 4, the weight of which was only half a grain, carried in one instance 1,417 grains, or 2,834 times its own weight.

"It required much patience to work with an arrangement so minute as this last; and it is probable that I might ultimately have obtained a larger figure than the above, which, however, exhibits a power proportioned to its weight far greater than any on record, and is eleven times that of the celebrated steel magnet which belonged to Sir Isaac Newton.

"It is well known that a steel magnet ought to have a much greater length than breadth or thickness; and Mr. Scoresby has found that when a large number of straight steel magnets are bundled together, the power of each when separated and examined is greatly deteriorated. All this is easily understood, and finds its cause in the attempt of each part of the system to induce upon the other part a contrary magnetism to its own. Still there is no reason why the principle should in all cases be extended from the steel to the electro-magnet, since in the latter case a great and commanding inductive power is brought into play to sustain what the former has to support by its own unassisted retentive property. All the preceding experiments support this position, and the following table gives proof of the obvious and necessary general consequence, the maximum power of the electro-magnet is directly proportional to its least transverse sectional area. The second column of the Table contains the least sectional area in square inches of the entire magnetic circuit. The maximum power in pounds avoirdupois is recorded in the third; and this, reduced to an inch square of sectional area, is given in the fourth column under the title of specific power."

TABLE I.

| Description. | | Least Sectional Area. | Maximum Power. | Specific Power. |
|---|---|---|---|---|
| My own electro-magnets | No. 1. ... | 10 | 2090 | 209 |
| | No. 2. ... | 0·196 | 49 | 250 |
| | No. 3. ... | 0·0436 | 12 | 275 |
| | No. 4. ... | 0·0012 | 0 202 | 162 |
| Mr. J. C. Nesbit's. Length round the curve, 3 feet; diameter of iron core, 2¾ in.; sectional area, 5·7 in.; do. of armature, 4·5 in.; weight of iron, about 50 lbs. ... | | 4·5 | 1428 | 317 |
| Prof. Henry's. Length round the curve, 20 in.; section, 2 in. square; sharp edges rounded off; weight, 21 lbs. ... ... ... ... | | 3·94 | 750 | 190 |
| Mr. Sturgeon's original. Length round the curve, about 1 ft.; diameter of the round bar, ½ in. | | 0·196 | 50 | 255 |

* "Scientific Papers," vol. i., p. 30.

"The above examples are, I think, sufficient to prove the rule I have advanced. No. 1 was probably not fully saturated; otherwise I have no doubt that its power per square inch would have approached 300. Also the specific power of No. 4 is small, because of the difficulty of making a good experiment with it."

These experiments were followed by some to ascertain the effect of the length of the iron of the magnet, which he considered, at least in those cases where the degree of magnetisation is considerably below the point of saturation, to offer a decidedly proportional resistance to magnetisation; a view the justice of which is now after 50 years amply confirmed.

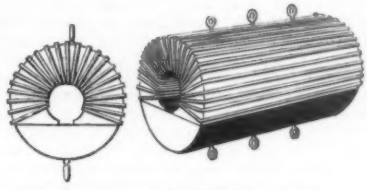


FIG. 7.—JOULE'S ELECTRO-MAGNET.

In November of the same year further experiments* in the same direction were published. A tube of iron, spirally made and welded, was prepared, planed down as in the preceding case, and fitted to a similarly prepared armature. The hollow cylinder thus formed, shown in fig. 8, was 2 feet in length, its internal

FIG. 8.—JOULE'S CYLINDRICAL ELECTRO-MAGNET.

diameter was 1·42 inch, its internal being 0·5 inch. The least sectional area was 10½ square inches. The exciting coil consisted of a single copper rod, covered with tape, bent into a sort of S-shape. This was later replaced by a coil of 21 copper wires, each $\frac{1}{10}$th inch in diameter and 23 feet long, bound together by cotton tape. This magnet, excited by a battery of 16 of Sturgeon's cast-iron cells, each one foot square and one and a-half inch in interior width, arranged in a series of four, gave a lifting power of 2,775 lbs.

Joule's work was well worthy of the master from whom he had learned his first lesson in electro-magnetism. He showed his devotion not only by writing descriptions of them for Sturgeon's "Annals," but by exhibiting two of his electro-magnets at the Victoria Gallery of Practical Science, of which Sturgeon was director. Others, stimulated into activity by Joule's example, proposed new forms, amongst them being two Manchester gentlemen, Mr. Radford and Mr. Richard Roberts, the latter being a well-known engineer and inventor. Mr. Radford's electro-magnet consisted of a flat iron disc, with deep spiral grooves cut in its face, in which were laid the insulated copper wires. The armature consisted of a plain iron disc of similar size. This form is described in Vol. IV. of Sturgeons "Annals." Mr. Roberts's form

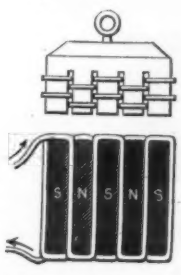



FIG. 9.—ROBERTS'S ELECTRO-MAGNET.

FIG. 10.—JOULE'S ZIG-ZAG ELECTRO-MAGNET.

of electro-magnet consisted of a rectangular iron block, having straight parallel grooves cut across its face, as in Fig. 9. This was described in Vol. VI. of Sturgeon's "Annals," p. 166. Its face was 6⅝ths inches square, and its thickness 2$\frac{1}{16}$ths inch. It weighed, with the conducting wire, 35 lbs.; and the armature, of the same size and 1½ inch thick, weighed 23 lbs. The load sustained by this magnet was no less than 2,950 lbs. Roberts

* "Scientific Papers," p. 40, and "Annals of Electricity," vol. v., p. 170.

inferred that a magnet, if made of equal thickness, but five feet square, would sustain 100 tons' weight. Some of Roberts's apparatus is still preserved in the Museum of Peel Park, Manchester.

On p. 431 of the same volume of the "Annals," Joule described yet another form of electro-magnet, the form of which resembled in general fig. 10; but which, in actual fact, was built up of 24 separate flat pieces of iron bolted to a circular brass ring. The armature was a similar structure, but not wound with iron. The iron of the magnet weighed 7 lbs., and that of the armature 4·55 lbs. The weight was 2,710 lbs., when excited by 16 of Sturgeon's cast iron cells.

In a subsequent paper on the calorific effects of magneto-electricity,* published in 1843, Joule described another form of electro-magnet of horseshoe shape, made from a piece of boiler-plate. This was not intended to give great lifting power, and was used as the field magnet of a motor. In 1852, another powerful electro-magnet of horseshoe form, somewhat similar to the preceding, was constructed by Joule for experiment. He came to the conclusion † that, owing to magnetic saturation setting in, it was improbable that any force of electric current could give a magnetic attraction greater than 200 lbs. per square inch. "That is, the greatest weight which could be lifted by an electro-magnet formed of a bar of iron one inch square, bent into a semi-circular shape, would not exceed 400 lbs."

With the researches of Joule may be said to end the first stage of development. The notion of the magnetic circuit which had thus guided Joule's work did not commend itself at that time to the professors of physical theories; and the practical men, the telegraph engineers, were for the most part content to work by purely empirical methods. Between the practical man and the theoretical man there was, at least on this topic, a great gulf fixed. The theoretical man, arguing as though magnetism consisted in a surface distribution of polarity, and as though the laws of electro-magnets were like those of steel magnets, laid down rules not applicable to the cases which occur in practice, and which hindered rather than helped progress. The practical man, finding no help from theory, threw it on one side as misleading and useless. It is true that a few workers made careful observations and formulated into rules the results of their investigations. Amongst these, the principal were Ritchie, Robinson, Müller, Dub, Von Kolke, and Du Moncel; but their work was little known beyond the pages of the scientific journals wherein their results were described. Some of these results will be examined in my later lectures, but they cannot be discussed in this historical *résumé*, which is accordingly closed.

### Generalities concerning Electro-magnets.

*Materials.*—In any complete treatise on the electro-magnet, it would be needful to enumerate, and to discuss in detail, the several constructive features of the apparatus. Three classes of material enter into its construction—first, the iron which constitutes the material of the magnetic circuit, including the armature as well as the cores on which the coils are wound, and the yoke that connects them; secondly, the copper which is employed as the material which conducts the electric currents, and which is usually in the form of wire; thirdly, the insulating material employed to prevent the copper coils from coming into contact with one another, or with the iron core. There is a further subject for discussion in the bobbins, formers, or frames upon which the coils are in so many cases wound, and which may in some cases be made in metal, but often are not. The engineering of the electro-magnet might well furnish matter for a special chapter.

### Typical Forms.

It is difficult to devise a satisfactory or exhaustive classification of the varied forms which the electro-magnet has assumed; but it is at least possible to enumerate some of the typical forms.

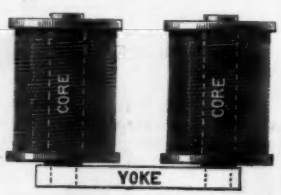



Fig. 11.—Typical Two-pole Electro-magnet.

1. *Bar Electro-magnet.*—This consists of a single straight core (whether solid, tubular, or laminated), surrounded by a coil. Fig. 3 (Electrical Review, September 19th, p. 329) depicted Sturgeon's earliest example.

2. *Horseshoe Electro-magnet.*—There are two sub-types included in this name. The original electro-magnet of Sturgeon (fig. 1, p. 329) really resembled a horseshoe in form, being constructed of a single piece of round wrought iron, about half an inch in diameter, and nearly a foot long, bent into an arch. In recent years the other sub-type has prevailed, consisting, as shown in Fig. 11, of two separate iron cores, usually cut from circular rod, fixed into a third piece of wrought-iron, the yoke. Occasionally this form is modified by the use of one coil only, the second core being left uncovered. This form has received in France the name of *aimant boiteux*. Its merits will be considered later. Sometimes a single coil is wound upon the yoke, the two limbs being uncovered.

3. *Ironclad Electro-magnet.*—This form, which has many times been re-invented, differs from the simple bar magnet in having an iron shell or casing external to the coils, and attached to the core at one end. Such a magnet presents, as depicted in Fig. 12, a central pole at one end surrounded by an outer annular pole of the opposite polarity. The appropriate armature for electro-magnets of this type is a circular disc or lid of iron.

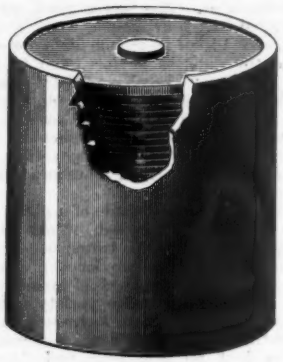


Fig. 12.—Iron-clad Electro-magnet.

4. *Coil and Plunger.*—A detached iron core is attracted into a hollow coil, or solenoid, of copper wire, when a current of electricity flows round the latter. This is a special form, and will receive extended consideration.

5. *Special Forms.*—Beside the leading forms enumerated above, there are a number of special types, multipolar, spiral, and others designed for particular purposes. There is also a group of forms intermediate between the ordinary electro-magnet and the coil and plunger form.

### Polarity.

It is a familiar fact that the polarity of an electro-magnet depends upon the sense in which the current is flowing around it. Various rules for remembering the relation of the electric flow and the magnetic force have been given. One of them that is useful is that when one is looking at the north pole of an electro-magnet, the current will be flowing around that pole in the sense opposite to that in which the hands of a clock are seen to revolve. Another useful rule, suggested by Maxwell, is illustrated by fig. 13, namely, that the sense of the circulation of the current (whether right or left-handed), and the positive direction of the resulting magnetic force are related together in the same way as the rotation and the travel of a right-handed screw are associated together. Right-handed rotation of the screw is associated with forward travel. Right-handed circulation of a current is associated with a magnetic force tending to produce north polarity at the forward end of the core.

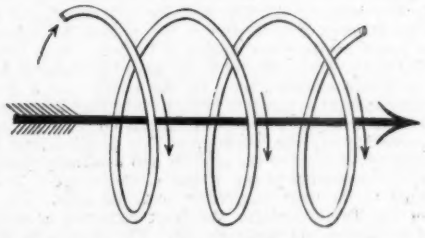


Fig. 13.—Diagram Illustrating Relation of Magnetising Circuit and Resulting Magnetic Force.

### Uses in General.

Regarded as a piece of mechanism, an electro-magnet may be regarded as an apparatus for producing a mechanical action at a place distant from the operator who controls it; the means of communication from the operator to the distant point where the electro-magnet is being the electric wire. The uses of electro-magnets may, however, be divided into two main divisions. For certain purposes an electro-magnet is required merely for obtain-

* "Scientific Papers," vol. i., p. 123; and "Phil. Mag.," Ser. 3, vol. xxiii., p. 263, 1843.

† "Scientific Papers," vol. i., p. 362; and "Phil. Mag.," Ser. 4, vol. iii., p. 32.

ing temporary adhesion or lifting power. It attaches itself to an armature, and cannot be detached so long as the exciting current is maintained, except by the application of a superior opposing pull. The force which an electro-magnet thus exerts upon an armature of iron, with which it is in direct contact, is always considerably greater than the force with which it can act on an armature at some distance away, and the two cases must be carefully distinguished. *Traction* of an armature in contact, and *attraction* of an armature at a distance, are two different functions. So different, indeed, that it is no exaggeration to say that an electro-magnet designed for the one purpose is unfitted for the other. The question of designing electro-magnets for either of these purposes will occupy a large part of these lectures. The action which an electromagnet exercises on an armature in its neighbourhood may be of several kinds. If the armature is of soft iron, placed nearly parallel to the polar surfaces, the action is one simply of attraction, producing a motion of pure translation, irrespective of the polarity of the magnet. If the armature lies oblique to the line of the poles there will be a tendency to turn it round, as well as to attract it; but, again, if the armature is of soft iron the action will be independent of the polarity of the magnet, that is to say, independent of the direction of the exciting current. If, however, the armature be itself a magnet of steel permanently magnetised, then the direction in which it tends to run, and the amount, or even the sign of the force with which it is attracted, will depend on the polarity of the electro-magnet, that is to say, will depend on the direction in which the exciting current circulates. Hence there arises a difference between the operation of a *non-polarised* and that of a *polarised* apparatus, the latter term being applied to those forms in which there is employed a portion — say an armature—to which an initial fixed magnetisation has been imparted. Non-polarised apparatus is in all cases independent of the direction of the current. Another class of uses served by electro-magnets is the production of rapid vibrations. These are employed in the mechanism of electric trembling bells, in the automatic breaks of induction coils, in electrically-driven tuning-forks such as are employed for chronographic purposes, and in the instruments used in harmonic telegraphy. Special constructions of electro-magnet are appropriate to special purposes such as these. The adaptation of electro-magnets for the special end of responding to rapidly alternating currents is a closely kindred matter. Lastly, there are certain applications of the electro-magnet, notably in the construction of some forms of arc lamp, for which it is specially sought to obtain an equal, or approximately equal, pull over a definite range of motion. This use necessitates special designs.

### The Properties of Iron.

A knowledge of the magnetic properties of iron of different kinds is absolutely fundamental to the theory and design of electro-magnets. No excuse is, therefore, necessary for treating this matter with some fullness. In all modern treatises of magnetism, the usual terms are defined and explained. Magnetism which was formerly treated of as though it were something distributed over the end-surfaces of magnets, is now known to be a phenomenon of internal structure; and the appropriate mode of considering it is to treat the magnetic materials, iron and the like, as being capable of acting as good conductors of the magnetic lines—in other words, as possessing magnetic *permeability*. The precise notion now attached to this word is that of a numerical coefficient. Suppose a magnetic force—due, let us say, to the circulation of an electric current in a surrounding coil—were to act on a space occupied by air, there would result a certain number of magnetic lines in that space. In fact, the intensity of the magnetic force, symbolised by the letter H, is often expressed by saying that it would produce H magnetic lines per square centimetre in air. Now, owing to the superior magnetic power of iron, if the space subjected to this magnetic force were filled with iron instead of air, there would be produced a larger number of magnetic lines per square centimetre. This larger number in the iron expresses the degree of magnetisation in the iron; it is symbolised * by the letter B. The ratio of B to H expresses the permeability of the material. The usual symbol for permeability is the Greek letter $\mu$. So we may say that B is equal to $\mu$ times H. For example, a certain specimen of iron, when subjected to a magnetic force capable of creating, in air, 50 magnetic lines to the square centimetre, was found to be permeated by no fewer than 16,062 magnetic lines per square centimetre. Dividing the latter figure by the former gives us the value of the permeability at this stage of the magnetisation 321, or the permeability of the iron is 321 times that of air. The permeability of such non-magnetic materials as silk, cotton, and other insulators, also of brass, copper, and all the non-magnetic metals, is taken as 1, being practically the same as that of the air.

This mode of expressing the fact is, however, complicated by the fact of the tendency in all kinds of iron to magnetic saturation. In all kinds of iron the magnetisability of the material becomes diminished as the actual magnetisation is pushed further. In other words, when a piece of iron has been magnetised up to a certain degree it becomes, from that degree onward, less permeable to further magnetisation, and, though actual saturation is never reached, there is a practical limit beyond which the magnetisation cannot well be pushed. Joule was one of the first to establish this tendency toward magnetic saturation. Modern researches have shown numerically how the permeability diminishes as the magnetisation is pushed to higher stages. The practical limit of the magnetisation, B, in good wrought iron is about 20,000 magnetic lines to the square centimetre, or about 125,000 lines to the square inch; and, in cast iron, the practical saturation limit is nearly 12,000 lines per square centimetre, or about 70,000 lines per square inch. In designing electro-magnets, before calculations can be made as to the size of a piece of iron required for the core of a magnet for any particular purpose, it is necessary to know the magnetic properties of that piece of iron; for it is obvious that if the iron be of inferior magnetic permeability, a larger piece of it will be required in order to produce the same magnetic effect as might be produced with a smaller piece of higher permeability. Or, again, the piece having inferior permeability will require to have more copper wire wound on it; for in order to bring up its magnetisation to the required point, it must be subjected to higher magnetising forces than would be necessary if a piece of higher permeability had been selected.

A convenient mode of studying the magnetic facts respecting any particular brand of iron is to plot on a diagram the curve of magnetisation—i.e., the curve in which the values, plotted horizontally, represent the magnetic force, H, and the values plotted vertically those that correspond to the respective magnetisation, H. In fig. 14, which is modified from the researches of Prof. Ewing, are given five curves relating to soft iron, hardened iron, annealed steel, hard-drawn steel, and glass-hard steel. It will be noticed that all these curves have the same general form. For small values of H the values of B are small, and as H is increased B increases also. Further, the curve rises very suddenly, at least with all the softer sorts of iron, and then bends over and becomes nearly horizontal. When the magnetisation is in the stage below the bend of the curve, the iron is said to be far from the state of saturation. But when the magnetisation has been pushed beyond the bend of the curve, the iron is said to be in the stage approaching saturation; because at this stage of magnetisation it requires a large increase in the magnetising force to produce even a very small increase in the magnetisation. It will be noted that for soft wrought iron the stage of approaching saturation sets in when B has attained the value of about 16,000 lines per square centimetre, or when H has been raised to the value of about 50. As we shall see, it is not economical to push B beyond this limit; or, in other words, it does not pay to use stronger magnetic forces than those of about H = 50.

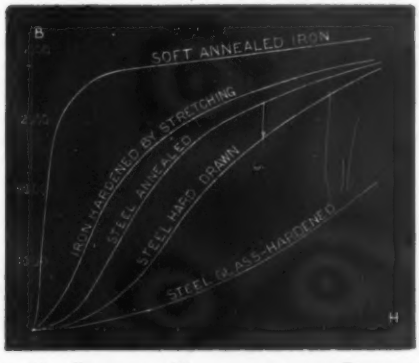



FIG. 14.—CURVES OF MAGNETISATION OF DIFFERENT MAGNETIC MATERIALS.

### Methods of Measuring Permeability.

There are four sorts of experimental methods of measuring permeability.

1. *Magnetometric Methods.*—These are due to Müller, and consist in surrounding a bar of the iron in question by a magnetising coil, and observing the deflection its magnetisation produces in a magnetometer.

2. *Balance Methods.*—These methods are a variety of the preceding, a compensating magnet being employed to balance the effect produced by the magnetised iron on the magnetometric needle. Von Feilitzsch used this method, and it has received a

* The following are the various ways of expressing the three quantities under consideration:—

B—The internal magnetisation.
The magnetic induction.
The induction.
The intensity of the induction.
The permeation.
The number of lines per square centimetre in the material.

H—The magnetising force at a point.
The magnetic force at a point.
The intensity of the magnetic force.
The number of lines per square centimetre that there would be in air.

$\mu$—The magnetic permeability.
The permeability.
The specific conductivity for magnetic lines.
The magnetic multiplying power of the material.

more definite application in the magnetic balance of Prof. Hughes. The actual balance is exhibited to-night upon the table, and I have beside me a large number of observations made by students of the Technical College by its means, upon sundry samples of iron and steel. None of these methods are, however, to be compared with those that follow.

3. *Inductive Methods.*—There are several varieties of these, but all depend on the generation of a transient induction current in an exploring coil which surrounds the specimen of iron, the integral current being proportional to the number of magnetic lines introduced into, or withdrawn from, the circuit of the exploring coil. Three varieties may be mentioned.

(*A*) *Ring Method.*—In this method, due to Kirchhoff, the iron under examination is made up into a ring, which is wound with a primary, or exciting coil, and with a secondary, or exploring coil. Determinations on this plan have been made by Stowletow, Rowland, Bosanquet, and Ewing; also by Hopkinson. Rowland's arrangement of the experiment is shown in fig. 15, in which B is the exciting battery; S, the switch for turning on or reversing the current; R, an adjustable resistance; A, an ampère-metre; and B G the ballistic galvanometer, the first swing of which measures the integral induced current. B C is an earth conductor or reversing coil wherewith to calibrate the readings of the galvanometer, and above is an arrangement of a coil and a magnet to assist in bringing the swinging needle to

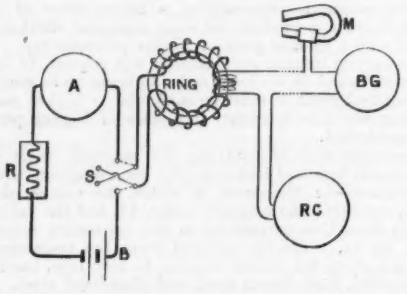



FIG. 15.—RING METHOD OF MEASURING PERMEABILITY (ROWLAND'S ARRANGEMENT).

rest between the observations. The exciting coil and the exploring coil are both wound upon the ring; the former is distinguished by being drawn with a thicker line. The usual mode of procedure is to begin with a feeble exciting current, which is suddenly reversed, and then reversed back. The current is then increased, reversed, and re-reversed; and so on, until the strongest available points are reached. The values of the magnetising force, H, are calculated from the observed value of the current by the following rule. If the strength of the current, as measured by the ampère-meter be $i$, the number of spires of the exciting coil, S, and the length, in centimetres, of the coil (*i.e.*, the mean circumference of the ring) be $l$, then H is given by the formula—

$$H = \frac{4\pi}{10} \times \frac{S\,i}{l} = 1{\cdot}2566 \times \frac{S\,i}{l}.$$

Bosanquet, applying this method to a number of iron rings, obtained some important results. In fig. 16 are plotted out the values of H and B for seven rings. One of these, marked J, was of cast steel, and was examined both when soft and afterwards when hardened. Another, marked I, was of the best Lowmoor iron. Five were of Crown iron, of different sizes. They were marked for distinction with the letters G, E, F, H, K. In the accompanying Table are set down the values of B at different stages of the magnetisation.

TABLE OF VALUES OF B IN FIVE CROWN IRON RINGS.

| Name. | G. | E. | F. | H. | K. |
|---|---|---|---|---|---|
| Mean diam. bar thickness. | 21·5 cm. 2·635 | 10·065 cm. 1·298 | 22·1 cm. 1·292 | 10·735 cm. 0·7137 | 23·725 cm. 0·7544 |
| Magnetising force. | | | | | |
| 0·2 | 126 | 73 | 62 | 82 | 85 |
| 0·5 | 377 | 270 | 224 | 208 | 214 |
| 1 | 1,449 | 1,293 | 840 | 675 | 885 |
| 2 | 4,564 | 3,952 | 3,533 | 2,777 | 2,417 |
| 5 | 9,900 | 9,147 | 8,293 | 8,479 | 8,884 |
| 10 | 13,023 | 13,367 | 12,540 | 11,376 | 11,388 |
| 20 | 14,911 | 14,653 | 14,710 | 14,066 | 13,273 |
| 50 | 16,217 | 15,704 | 16,062 | 15,174 | 13,890 |
| 100 | 17,148 | 16,677 | 17,900 | 16,134 | 14,837 |

I have the means here of illustrating the induction method of measuring permeability. Here is an iron ring, having a cross-section of almost exactly one square centimetre. It is wound with an exciting coil supplied with current by two accumulator cells; over it is also wound an exploring coil of 100 turns connected in circuit (as in Rowland's arrangement) with a ballistic galvanometer which reflects a spot of light on the screen. In the circuit of the galvanometer is also included a reversing earth-coil. As a matter of fact, this earth-coil is of such a size, and wound with so many convolutions of wire that, when it is turned over, the amount of cutting of magnetic lines is equal to 840,000, or is the same as if 840,000 magnetic lines had been cut once. By adjusting the resistance of the galvanometer circuit, it is arranged that the first swing due to the induced current, when I suddenly turn over the earth coil, is 8·4 scale divisions. Then, seeing that our exploring coil has 100 turns, it follows that, when in our subsequent experiment with the ring, we get an induced current from it, each division of the scale over which the spot swings will mean 1,000 lines in the iron. I turn on my exciting current. See: it swings about 11 divisions. On breaking the circuit, it swings nearly 11 divisions the other way. That means that the magnetising force carries the magnetisation of the iron up to 11,000 lines; or, as the cross-section is about 1 square centimetre, B = 11,000. Now, how much is H? The exciting coil has 180 windings, and the exciting current through the ampèremeter is just 1 ampère. The total excitation is just 180 "ampère-turns." We must, according to our rule given above, multiply this by 1·2566 and divide by the mean circumferential length of the coil, which is about 32 centimetres. This makes H = 7. So if B = 11,000 and H = 7, the permeability (which is the ratio of them) is about 1,570. It is a rough and hasty experiment, but it illustrates the method.

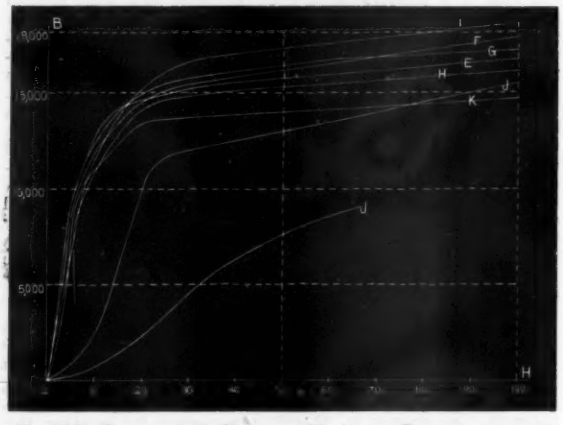



FIG. 16.—BOSANQUET'S DATA OF MAGNETIC PROPERTIES OF IRON AND STEEL RINGS.

Bosanquet's experiments settle the debated question whether the outer layers of an iron core shield the inner layers from the influence of magnetising forces. Were this the case, the rings made from thin bar iron should exhibit higher values of B than do the thicker rings. This is not so; for the thickest ring, G, shows throughout the highest magnetisations.

(*B.*) *Bar Method.*—This method consists in employing a long bar of iron instead of a ring. It is covered from end to end with the exciting coil, but the exploring coil consists of but a few turns of wire situated just over the middle part of the bar. Rowland, Bosanquet, and Ewing have all employed this variety of method; and Ewing specially used bars the length of which was more than 100 times their diameter, in order to get rid of errors arising from end-effects.

*(To be continued.)*

## ABSTRACTS OF PUBLISHED SPECIFICATIONS, 1889.

11426. "Improvements in the mode of driving, by means of electric motors, tramcars and other vehicles, and in apparatus for reducing in transmission to the axles of such vehicles the speed of rotation derived from electric and other motors." P. A. NEWTON. (Communicated from abroad by W. Main, of New York.) Dated July 16. 1s. 6d. Consists, in part, of an improvement upon what is commonly known as Watt's sun and planet gear. 8 claims.

11589. "Improvements in electric conductors, and in laying and supporting conductors within conduits." R. E. B. CROMPTON. Dated July 20. 8d. Relates to further improvements connected with Letters Patent No. 7655 of the 25th May, 1888. 5 claims.

11847. "Improvements in the distribution of electrical energy." SIEMENS BROTHERS & Co. (Communicated from abroad by the firm of Siemens and Halske, of Berlin.) Dated July 25. 8d. Claims:—1. The method of distributing electrical energy wherein three or more secondary conductors that supply the groups of consuming apparatus are combined with one or more current

generating machines and one or more transformers in such manner that the current generating machine or machines is or are connected by two main leads to the primary coil of the transformer the secondary coil of which is divided into sections which are connected to the said three or more secondary conductors substantially as described. 2. The modification of the method of distribution referred to in the preceding claim wherein the transformers consist of motor-generators having two or more generator armatures and driven by the current from the main current generator, the generator armatures of the motor transformers being coupled in series and connected to the said three or more secondary conductors substantially as described.

12772. "Improvements in means or apparatus for the generation and conversion of electric energy." A. DE CASTRO. Dated August 13. 8d. Consists in the employment of finely subdivided or comminuted magnetisable metal, usually iron filings, arranged in such way as to be loose or free to move, so that the particles may vibrate, and subjected to the action of magnetic lines of force derived either from permanent or electro-magnets, or from an exciting coil or coils. 4 claims.

12982. "Improvements in actuating mechanism for electrical switches." T. BARTON. Dated August 17. 6d. Claim:—The combination of a pulley or roller working against a lever actuated by a spring or working against a spring only, of special design, without the lever, and applied for the purpose of forcing the contact maker home in both directions, and applied to a switch for making and breaking electric circuits.

13371. "Improvements in electric telegraphic apparatus, applicable also to other electric signalling or indicating apparatus." T. H. PARKER and G. W. FAIRALL. Dated August 24. 8d. Has for its object to automatically relay from a battery the particular current which may be in circuit, whether it be of the positive or negative kind, and further to deflect the needle or actuate any other electrical instruments in a much more sensitive or economical manner than has been previously done. The relay instrument consists of five or more permanent magnets, upon each of which is mounted an electro-magnet, by which induced magnetism is obtained; two of these require to be positive, two negative, and the other either positive or negative, as may be prefered. 3 claims.

13859. "Regulator for electric lighting." E. J. HOUGHTON. Dated September 3. 6d. Claim:—1, The gradual insertion in or withdrawal from a circuit of resistance by means of a solenoid and vessel containing mercury or other conducting fluid.

14162. "Improvements in treating and rectifying or ageing alcohol or alcoholic liquors or the like by electricity." A. DE MERITENS. Dated September 7. 4d. Claim:—In the treatment and rectification or ageing of alcohol or alcoholic liquors and the like by electrical action the employment of a salt such as bi-sulphite of soda for the purpose described.

18018. "Improvements in electro-magnetic brakes for railway and similar vehicles and in means for increasing the adhesion between the wheels and rails." A. J. BOULT. (A communication from E. E. Ries and A. H. Henderson, of America.) Dated November 12. 8d. This invention has reference to a system of electro-magnetic brakes for wheeled vehicles, more especially for railway cars, and the same is combined with and is designed to operate in conjunction with a system of electro-magnetic traction increasing devices, for which letters patent have been obtained of Great Britain, No. 4,280, dated 20th March, 1888. 18 claims.

## THE VALUE OF DETAIL IN THE CARE AND LABOUR OF ELECTRIC LIGHT STATIONS.*

By A. J. DE CAMP.

IT certainly is a fact apparent to any one who has had the handling of electric light stations, that it is essentially a business of detail. The larger items about the business are very easily handled. They will take care of themselves if they are put in the right direction; but there is an infinite number of small things which very materially affect the successful operation of an electric light station. As an illustration of what I mean by that term, I will say that after considerable reflection and dividing the items worthy of care and attention in the management of the business under fifty heads, all of which have to be kept track of, and all of which are a positive and a direct item of expense or income, I find five items which I have had to class as miscellaneous expenses. These include all those items of expense which have a bearing on the business in general, not chargeable to any one of the particular heads under which I have seen fit to group the business. I find that the amount involved in miscellaneous items for the last year, in one company, was about $15,000; the space occupied on the books of the company to cover these small items was twice as much as the whole of the other part of the business. The items there reached from one penny up. There is no doubt but that detail may be carried to such an extent that it becomes burdensome. It may become unprofitable on some particular item, but we can only treat this matter as a whole. In one item of carbons alone the reduction in the expense of the carbon caused after a system was adopted by which they were accounted for on the basis of the inches, there was a saving of nearly 50 per cent. in that item alone.

Another important thing is the matter of discipline, because it is utterly impossible to get the detail part of your business thoroughly carried out unless you have a thorough discipline about your station. The most important item in the whole operation of an electric light station in point of dollars and cents is that of labour, and I do not see but what it will always be the case. I remember there was a time when we thought that sixty lamps on an ordinary circuit was a day's work for a man. Now they trim a hundred lamps more easily than they used to trim sixty, and my own judgment is that in the course of time we will work up so that 150 will be no harder than 100.

A custom of dealing with labour, I think, which requires the accounting of every minute of time for which a man is employed, has a very beneficial effect. I think that alone can be credited with a reduction in the pay-roll of some 25 per cent. A custom has been adopted by me of having a slip furnished to the workman by which he accounts for every hour of service; this gives the man who has charge of him an opportunity of judging for himself whether that man has employed his time properly during the ten hours. In the early history of the business it was the custom of my company to do a great deal of work without charge. That was done for policy sake. The number of men apparently required for the operation of the station was very far in excess of what anybody ever represented it to be or supposed it to be. In looking into it, we found that there were two or three men working here, and two or three there, and three or four somewhere else. What were they doing? Well, they were making changes, shifting the position of lamps—they were doing this, that, and the other thing. Well, we were going to be through with that and let these men go, we thought. But the fact is they never did go—they hung right straight on all the time. We closed that month and started in the next on the basis of charging for all work. The basis of the charge was mainly for the labour, charged at 30 cents. an hour, and all waste materials. We did not charge for anything that would be incorporated into our own property.

At that time, I think, we were running about 350 lights, and when at the end of the month we charged that up and it amounted to over $800. We tried to collect it, but I presume we did not collect more than $200 out of the $800. People demurred and would not pay it. But it brought the thing to an understanding. Now, no work is done after the first installation unless it is to be paid for by our customer, and we get an order from our customers in which they order the work to be done and to charge it to their account. That brought the next month's charges down, and all we had occasion to charge them was something less than $200. There could be no better proof in the world than that very fact that, as long as people did not have to pay for a thing, they were very free to indulge their fancies.

Another point: We send a man out to do a job and he comes in and charges three, four, five, six, or ten hours' time. The man for whom that work is done cannot account for more than an hour or two. Then comes your discussion on the payment of that account, and it is as a great trouble. We know nothing; we charge a man's time from the time he leave the station till the time he gets back and reports to us, and whether he has put in that amount of time, less the

* Delivered before the N. E. L. A., Cape May, August 20th, 1890.

time of coming and going, of course we have no means of knowing; at least, we did not, but we get nearer to it now. That is one of the things that takes a great deal of time, and I have noticed that our charges for that sort of work are very much more equitable, according to the judgment of our customers, than they have been heretofore; and, moreover, we find that the men do a great deal more work.

Another question which I think can be very profitably discussed is that which relates to small matters of income on your revenue account. The electric lighting business is not in such condition that you can take the ordinary stand and say to the public, "You will take just what we can give you, and just as we want to give it to you, or get nothing." We make our contracts as specific as we can; but we have not got a contract under which we have not given more service than we agreed to give in that contract. The service rendered is never below the standard. We have lights running on the 12 o'clock service plan; and our contracts for that service cover seven hours of maximum burning. That would mean strictly that at no time was the service rendered by those lights to exceed seven hours, which, in the winter months, is from five to 12. But that does not do, because five o'clock is not early enough in three or four months of the year, when the lamps are sometimes lighted as early as three o'clock. It means rather an average of seven hours than it does a maximum of seven hours. In any city where there is a restriction on the running of wires, it is necessary that you put half night lights on all night circuits, with the object and purpose of switching them off, individually perhaps at 12 o'clock. A customer can hardly be relied upon to do that, and the only safe way to do it is to have them switched off by your own *employés*. It is the same with all night lights, which might be run, and sometimes are run. Those conditions must be met. You must give the people what they want, or you will finally lose your business, and you will have to be getting new business all the time.

As long as I have been connected with this association, and as large an acquaintance as I have among electric light central station men, I never have found any one yet who seemed to have any appreciation or any interest in knowing just exactly what his product cost him on the same basis on which he sold it. To get at the cost of a light, or of any particular part of it, it is very generally figured up as a horse-power. But the point that I have always contended for is this. I rent a light for a given length of time, for a year, if you choose, which is the most favourable contact that I consider that we can make, because it gives us the longest service. In doing that you figure it on the basis to furnish light 312 nights per year, which you sell at so much per light. Now, you really want to know, not what the 312 lights cost you, and how much you get for them, and take the difference, and let that be profit or loss just as it happens to be, but you want to know just what each one of these lights cost you, and you want to know it as a whole; you do not want to know whether it takes one horse-power or two horse-power, or half a horse-power, as there are a great many other things besides horse-power that enter into this question.

Another thing that I find to be a very common practice is, to have a uniform price for a light of a certain character, whether the contract is for furnishing light for six months or for a year. The same rate for the longer and the shorter term is unjust to your long contract customers. It is a very easy thing to rent lights during six months of the year, commencing the first of September, October or November, and it is a very easy thing to keep such customers, because they want the lights most at that time. But in the summer time people discontinue the use along about the first of March, April, May or June, and so you have an idle lamp during the summer, in which you have your money invested. I contend that the user of that lamp has no right to expect to get that light at the same price per diem as the man who pays you for a service of 312 nights in the year. But that is almost universally done. There is just as much reason for a graduated scale of prices based upon the amount of service you get from your customer as there is for fixing the price for a 10 o'clock circuit, a 12 o'clock circuit, or an all-night circuit.

When that first became apparent to me the first effort I made to equalise the prices on that basis showed me that there was really nothing to go upon excepting guess work. After the first year's experience I had the result of my own experience to go by, by means of which I could work it out in a little better shape. But I found myself doing an injustice to our customers when I thought that I was doing an injustice to myself. I found that I was charging more people too much on that basis and others too little. This puts the company in the position of making a uniform contract in which they can say to every customer, or to every person that comes into the office, that the company will duplicate for him any contract that it has on its books.

## INDIAN TELEGRAPHS.

THE following information respecting the telegraphs of British India is extracted from the "Moral and Material Progress and Condition of India." The length of telegraph line and cable in India is now 33,462 miles, of which 1,568 miles represent the extensions of 1888–89. The number of messages for that period were 2,978,888, an increase of 176,669 over the previous year. The increase of messages was wholly under the head of "private messages," there having been a considerable decrease in the number of State or public service messages. The receipts were Rx. 632,247, yielding a surplus of Rx. 198,024 on the revenue account, and equal to 4·45 as against 5·46 per cent. in the preceding year on the capital outlay. The decrease of receipts was due to the reduction in the number of State messages, especially in Burmah.

The additions to the capital expenditure during the year amounted to Rx. 174,362 or Rx. 60,593 less than the previous year. On the Indo-European Telegraph line *viâ* Teheran the nett revenue was £19,138, equal to 1¾ per cent. on the capital outlay of £1,124,126, but if the line be debited with the annuity of Rx. 18,827, payable to the shareholders of the late Red Sea Telegraph Company, the surplus of the year is reduced to Rx. 1,111.

## CORRESPONDENCE.

### Electrical Heterodoxy.

Having read your article in last week's issue on "Electrical Heterodoxy," it recalled to memory a little piece of apparatus I devised some years ago, for the amusement and instruction of some juvenile friends. I think it gives experimental proof of your explanation of the test tube experiment.

An ordinary school slate is taken, and the slate removed and a sheet of glass inserted in the frame. In the centre of one side of this glass is attached a sheet of tinfoil, and to centre of foil is attached a smooth, round-ended cork neatly covered with tinfoil; from end of cork projected a small metal ball. The sketch represents a section.

On warming the apparatus and rubbing the plain surface of glass with a piece of silk for a short time, a spark may be drawn from the projecting ball on opposite side of glass.

Must I conclude the electricity passed from the rubbed side and through the system and out by the ball? Without going into the controversy of whether electricity is generated or separated, the explanation the juveniles received was, that, by the expenditure of an amount of muscular energy, the plain surface is positively electrified, which induces a negative char e

on the other surface, thus disturbing the electric equilibrium of the whole system with the result of the exhibition of positive electrification on the ball.

The fact that electricity did not pass through the glass was shown in a very simple way, holding the slate horizontally, cork down, and placing a sheet of foil on the glass, then connecting it with the ball by means of a discharger, when a second spark occurs, and the equilibrium is restored.

A, A, Slate frame; B, Sheet of glass; C, Tinfoil: D, Cork and projecting ball; + —, Shows condition of electrification, though — sign should be between foil and glass.

Now, I think, this exactly shows what occurs in the test tube experiment, the inner surface of which is represented by the uncoated surface of the glass. To my mind, this test tube experiment of the apparent passage of a spark through the glass, rather points to the probability that conduction is an effect of polarisation.

Assuming the spark an evidence of conduction, and its passage an evidence of current, then if the conduction is absolute, the glass should be perforated; but, no, there is a break of continuity, and this assumed current takes another quality, and one that we can grasp, it apparently gets through that glass; but how, and does it get through? No, it takes up the quality assigned to induction, the dielectric glass is polarised, we know the inner and outer surface of the end of that test tube must be under a state of polarisation, one surface being positively electrified and the other negatively; this is a fact, because we know the effect produced by a charge in this way.

Are we driven to the conclusion that that which we call current has passed by conduction through the glass by the agency of polarisation or induction; if this be so, then what is the difference between conduction and induction, and are they not *both* explainable by polarisation? The glass end of the test tube is equally a portion of the path; then why should we conclude the energy passed through the air space by conduction and through the glass by induction; rather should we say the whole passage is completed from atom to atom through the agency of polarisation, and therefore induction, or equally conduction; but why this clashing of words, why not say at once, polarisation?

I do not see that the insulated gas flame experiment proves more than that the flame is electrified in sign similar to that from which it is deflected. I have not seen the original description of the experiment, but base my conclusion on the description in your issue of last week. It does not follow that because we speak of + and − electrification and polarisation that we believe, or even assume, there are two forces.

There is such a thing as stress and strain, and I, for one, can see no reason why we should consider electric stress and polarisation as distinct. I am firmly of belief the generation of current by the passage of a conductor across a magnetic field is one of strain, and bearing in mind that if a bar of copper be suspended in a magnetic field, it will, diamagnetically, set in a definite direction. What occurs if that bar is urged through the field in a *definite position*? Must there not be a strain on the particles of that bar, and will they not turn toward the position in which the bar would set if free, and return from that position as the bar passes out of the field, do not the atoms, molecules, or particles of that bar oscillate, turn or rotate?

What do we find when the bar is in closed circuit and approaches and enters the field, and as the atoms, molecules, or particles are strained, a current of electric energy is urged in one direction, and as the bar passes out of the field and the atoms, molecules, or particles swing back, a current of electric energy is urged in opposite direction? Shall we not call this straining or swinging back dynamic or oscillating polarisation, and polarisation in which set occurs, static polarisation? Having got thus far, is it possible that Faraday, Tyndall, and others, in their brilliant diamagnetic experiments, omitted to test whether an electrostatic effect is produced by resisting the diamagnetic movement through fixing, say, the bar of copper, and thus allow the atoms, molecules, or particles to assume a polarised set?

It would be an instructive discovery to find by diamagnetic experiment that the set polarisation means static electrification, and the oscillating polarisation dynamic electricity. There is room for thought and experiment in this direction.

**Henry Sutton.**

*September 13th*, 1890.

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### French v. English Steel.

Kindly insert the enclosed letter in your valuable REVIEW, and oblige, yours respectfully,

**J. A. Parkes.**

*September 19th*, 1890.

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"19th Sept., 1890.

"W. H. Preece, Esq., F.R.S.

"Sir,—I have been much interested by reading in the ELECTRICAL REVIEW the report of your paper on the quality of magnetic steel, and much pleased to observe that the sample magnets made by Mr. Marchal are superior to the others. The cause of my satisfaction is that the steel used in making these samples was furnished by me to Mr. Marchal. I have supplied him for some years past, and the magnets which procured him the only award given specially for magnets in the Paris Universal Exhibition of last year were also made of MM. Levick, M'Gillivray & Co.'s steel sold by my intermediary to Mr. Marchal.

"Your conclusion, therefore, that French steel is better than English needs modifying. Nevertheless, I shall not envy the reputation of French steel, if the French Government and public companies continue to purchase of me as heretofore.

"I hold myself at your service to furnish any further information that can be of use to you in pursuing your interesting and practically useful investigations.

"I am, Sir,

"Yours very respectfully,

"J. A. PARKES,

"*Paris Agent of Levick, M'Gillivray & Co.*"

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### Prof. Elihu Thomson's Alternator.

The publication of an abstract of my specification describing an alternating dynamo of new design has elicited some correspondence in your paper, concerning which I think I may make a few statements.

The principle of utilising the changes of magnetic force without reversal in generating currents is certainly not new, as I designed machines working on this principle as far back as 1877–78.

The merit of the new machine is that it is a practicable machine to build and to operate, and at the same

time that its efficiency will undoubtedly be high, as the preliminary tests of a machine built to run 1,000 lights have shown that it can carry 1,500 lights quite efficiently. The indications go to show that machines can be made to have a commercial efficiency of 90 per cent. or over.

I am tempted to be somewhat amused at the criticisms made on the character of the Field as being inefficient, and I refer particularly to the statement of Pyke and Harris in their letter appearing in your issue of August 29th :—"Whereas, in Prof. Thomson's machine, it is apparent there is a considerable loss in the Field, more particularly the revolving part of the same." Now, it happens that the machine, as constructed, shows no evidence of any heating in the revolving portion as well as other portions; but, on the other hand, that this portion of the machine keeps delightfully cool, and that the heating is in the wire and only that due to whatever density of current may at any time be flowing.

Concerning the theory of the machine, it may not be out of place to give my views on the subject. I do not think that the stationary iron which supports what may be termed the armature bobbins, is entirely free from reversals of magnetism, but that under heavy loads there may be slight reversals occurring in certain portions of the iron, due to the flow of the armature currents themselves, and particularly those portions influenced by the armature wire which are not at the same time under the influence of the field poles. Whether the lines of magnetism are actually carried around with the revolving consequent poles or not is a question which it is difficult to answer, but the actions would be the same whether they are or not. If they are carried around by the consequent pole, the coils opposite them or the armature wire would be cut by concentrated bundles of lines issuing from the revolving consequent pole to the exterior iron, and if the lines do not rotate with the pole, then the armature wire would be cut by lines springing back from one division of the consequent pole to the next succeeding division as such pole revolves.

The details of the design will probably determine which of these actions will take place, and, in most cases, perhaps both the actions of bundles of lines carried forward, combined with the recession of lines backwards from one division of the revolving pole to the next succeeding, may really take place.

In the large machine which I have, the laminated iron carrying the armature coils or induced coils is divided into a number of sections or segments of a ring, and machines have also been built in which there is no iron projecting from the outer laminated portion towards the revolving pole. In this case, of course, the closure of the magnetic circuit is almost uniform throughout the revolution.

I had not intended to publish anything concerning this machine until the work of building and testing the machines of large size had been completed, but the extracts from my specification have led to sufficient discussion to warrant me in making the statements preceding.

**Elihu Thomson.**

Lynn, Mass., *September 10th*, 1890.

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### Re The Bath Installation.

In reply to Mr. Massingham's letter I wish to point out that my quarrel was on September 3rd. The alleged carelessness was based on an accident occurring at midnight, September 1st.

You will find on referring to my report of the breakdown of August 31st, dated September 1st (and which was written early in the morning, posted to catch an early mail, and which would be delivered at your office during the afternoon or evening), that I did not conceal the fact that I was working on the installation.

With the failure of August 31st, due to carelessness in the boiler-house, I, as engine-driver, had nothing to do, and you will find the information I supplied you with to be correct, should you care to make further enquiries.

You are at liberty to publish all the above or any extract of it with my full name and address.

**Charles Powell.**

*September 22nd*, 1890.

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### Fire Office Rules.

As you have mentioned my name in connection with the recent correspondence in the *Times*, of which the leading article on Fire Risk Rules in your issue of the 20th inst. is the result, perhaps you will permit me to make a few further remarks on the subject.

There is unfortunately a tendency in certain quarters to make light of the difficulties incidental to electric light wiring, and an idea that no great experience is required to enable anyone acquainted with the ordinary principles of electrical science to draw up trustworthy rules.

Contractors and others who have experienced the unforeseen, perplexing, and vexatious failures of insulation that from time to time occur even with the best of work and material, will agree that this is not the case at all, and that the practical difficulties are in some cases much greater than many apprehend.

As I have already stated in the *Times*, it is much to be desired that, if an electrical committee be appointed by the Institution of Electrical Engineers, or any one else, to confer with the insurance companies and draw up new rules, care shall be taken to arrange that the majority of those forming such a committee be men having a real practical experience of the subject from the contractors and supply companies points of view, and not mere secondhand information or theoretical knowledge, however eminent.

That a word of warning is required as to this, is evident from a glance at the names of those who composed the committee that drew up the existing Institution Fire Rules. The list comprises men of the highest distinction and standing in the electrical world; men whose services to science it would be impossible to overestimate; but among the whole 22 names, of which seven are those of professors, there are not above half-a-dozen who can possibly have had any practical experience of electrical wiring—at all events, as commercially carried out.

Prof. S. P. Thompson has recently designated the Institution Rules as "a dead letter," and as "invertebrate." On the contrary, they are in many respects an admirable set of regulations, but it is idle to deny that they are capable of considerable improvement, and that a committee having a larger admixture of the practically experienced element could now frame a set very superior in many particulars.

The electrical industry will, I am confident, agree as to this :—If any one set of rules is to be universally and exclusively adopted, let us have these rules as perfect and as definite as practical experience can make them. Let these rules clearly state what is and what is not admissible, and distinctly differentiate between those regulations that are obligatory and those that are merely recommended. Let us have a thoroughly competent committee to draw the rules up, and let this committee be a standing one, so that the rules may be revised from time to time as the progress of electrical science and the accumulation of experience renders this necessary.

By whom, whether the Institution of Electrical Engineers or the Electrical Trades Section of the London Chamber of Commerce, such a committee, is appointed, is of secondary importance, provided the insurance companies are satisfied and due weight and authority be assured. The real question of moment is the constitution of the committee itself and the practical competence of those who serve on it.

**A. A. Campbell Swinton.**

*September 22nd*, 1890.